March, 1987

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Published by the Director, IGFRI, Jhansi-284003 and Printed at Agrawal Press, Jhansi
The Indian Grassland and Fodder Research Institute, Jhansi, established in 1962, is conducting basic and applied research on all facets of fodder crops, grasses and grasslands. Consorted efforts in the areas of Research, Training and Extension are being made to bridge the widening gap between the demand and supply of forages and feeds in the country. This task became more difficult due to shift of land to food and cash crops and restricting forage production largely to natural grasslands, wastelands and community lands, while very little to cultivated land. The task is difficult as well as challenging since most production areas are marginal or degraded which require very careful management under disturbed ecological situations.

The Institute continued its efforts to carry out inter-disciplinary research on evolving high yielding, superior fodder and pasture crop varieties, developing agrotechniques for maximising forage production from irrigated, rainfed and problem areas, improving biomass production from marginal and degraded lands through improved grassland management, silvipasture and agro-forestry systems, evolving better seed production techniques, plant animal systems research, design and development of farm tools and implements for specific situations including harvest and post harvest technologies and finally test their economic viability before transferring from research farms to farmers land. Providing training to national and international research and development personnels from various departments and transfer of technology were important area of activities during the year. The work done on the above aspects in 1985 has been included in this report, which I hope, would be useful to research and development workers and also to those concerned with forage production and utilization.

I sincerely thank all my colleagues in the Institute particularly to the members of the publication committee for their efforts put in bringing out this report.

March, 1987

IGFRI, Jhansi

PANJAB SINGH
Director
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Feeding of livestock judiciously with nutritious forages is very crucial for ensuring optimum level of milk, meat, wool and egg production. One of the major factors that limits the expected level of production is wide gap between the requirement and availability for feeds forages. The importance of forages in feeding livestock, the ever increasing gap between supply and demand, the diversity and complexity of the problems and their impact on agricultural economy of the country led to the establishment of the Indian Grassland and Fodder Research Institute, Jhansi towards the end of Third Five Year Plan in 1962 by the Government of India and administered by the Indian Council of Agricultural Research, New Delhi from April 1966.

OBJECTIVES

In order to fulfil the responsibility of national mandate of research on forage and feed resources, the Institute has the following objectives:

- To carry out basic and applied research on grasses, grasslands and fodder crops and to collate, coordinate and collaborate research in the country by centralising direction, operation and superintendence.

- To evolve high yielding, fertilizer responsive, disease and pest resistant and superior quality forage crop varieties suited to different farming systems in various agro-climatic regions of the country by the use of modern techniques of the plant breeding and through the application of research in other cognate disciplines.

- To develop agro-techniques for maximising forage production in irrigated, rainfed, dry and other problem areas by evolving appropriate cultural-cum-fertilizer practices, intensive crop rotations, soil-water management systems, systems analysis and crop modelling, agro-forestry, pasture and rangeland management.
To carry out studies on soil survey and land use, physiochemical characterization of forage growing areas, soil fertility and plant nutrition, biological nitrogen fixation and amelioration of problem soils for forage production.

To undertake investigations on natural grassland/degraded rangelands for improving their productivity through ecological principles, species combinations and establishment management techniques under different grass covers of the country.

To develop and evaluate various crop/tree species combinations for silvi-pasture, horti-pasture and agroforestry systems for enhancing forage, fuel and timber production from marginal and submarginal wastelands under different agro-climatic regions of the country.

To conduct basic and applied research on nutritional evaluation of cultivated forage/pasture species including non-conventional plants and crop residues, their conservation, fortification and utilization for optimum production.

To conduct research on all aspects of forage seed production and evolve suitable control measure for protecting seed during storage from diseases and pests.

To study various facets of the problems of the weeds in cultivated fodders and grasslands and evolve economic measures for their control.

To design and fabricate efficient, low cost, labour saving farm machinery and implements from indigenous materials to meet the diverse needs with special reference to forage cultivation on small farm holdings.

To undertake investigations on statistical designs, sampling techniques and economic analysis related to herbage and seed production in forage crops/systems.

To develop appropriate extension techniques for transfer of recommended technology, get feedback information for further investigation and to disseminate knowledge on the subject through organised training programmes.

ORGANISATION

The Institute is located at Jhansi (78° 35' E longitude, 25° 26' N latitude and 275 m altitude) about 10 km from the town on Jhansi–Gwalior road. The Institute is organised in following eleven scientific divisions:
(i) Plant Improvement  
(ii) Agronomy  
(iii) Soil Science  
(iv) Grassland Management  
(v) Agro-Silvipasture  
(vi) Seed Technology  
(vii) Plant Animal Relationship  
(viii) Weed Ecology and Control  
(ix) Agricultural Engineering and Post-Harvest Technology  
(x) Rural Economics and Biometrics  
(xi) Extension and Training.

It has nine Central units viz (i) Administration (ii) Audit and Accounts (iii) Estate (iv) Farm (v) Library (vi) Technical Cell (vii) Photography and Arts (viii) Central Laboratory Service and Research and Development Cell. The Institute is the headquarter of All India Coordinated Project for Research on Forage Crops having its main and sub centres in various parts of the country. Besides, Institute also houses research centres of All India Coordinated Projects on (i) Dryland Agriculture (ii) Agroforestry (iii) Under-utilized and under-exploited Plants (iv) Prototype Testing and Feasibility and (v) National Seed Project. The Institute has also research collaboration at International level through two International Projects viz. IDRC-IGFRI Silvipasture Operational Research Project and PL-480 Project on weed management Research in Food-Fodder Production System.

For conducting researches for the higher altitude temperate, alpine and hilly regions extending over the States of J & K, Himachal Pradesh, Uttar Pradesh, West Bengal and North Eastern Regions of the Country, the Institute has established its regional station at Manasbal, Safapura (J & K).

RESEARCH COLLABORATION

The Institute with its pre-eminence on the subject and national mandate coordinates the research work on grassland and fodder production and also collaborates at national and international level.
A. National level:

(i) All India Coordinated Research Project on Forage Crops.

The Project is charged with the responsibility of formulating technical programme and monitoring research on all aspects of forage crops at different centres in various agro-climatic regions of the country. Through this Project, the Institute plays a leading role in fostering close cooperation with various State Agricultural Universities and Research Institutes.

(ii) National seed project (NSP)

The World Bank aided National Seed Project located at the Institute is responsible for production of breeder seed of released/notified forage crop varieties.

(iii) AICRP on Dryland Agriculture

The Centre of All India Coordinated Research Project on Dryland Agriculture is engaged in research work for evolving suitable integrated crop production strategy for drought prone areas of Bundelkhand based on watershed approach.

(iv) All India Coordinated Research Project on Agroforestry.

The centre of this project functions with emphasis on collection and evaluation of promising fuel, fodder and small timber producing species/cultivars with a view to work out suitable system for different situations.

(v) All India Coordinated Research Project on underutilized and under-exploited plants.

The centre started functioning at the Institute during last year for collection, evaluation, multiplication and testing of under-exploited and under-utilized plant species with special reference to sub-babool for various habitats and farming systems.

(vi) AICRP on Development, Testing and Prototype Production of Farm Implements and Machinery.

The centre of this project is in operation at the Institute for developing and testing the possibility of using improved agricultural implements and farm machinery in forage based farming systems and educating the farmers on usefulness, handling and maintenance of improved implements.
(vii) Watershed Management

The centre under the technical control of IGFRI for watershed management in Bangra area of Jhansi district has already been initiated. The watershed management plan of this area has been implemented.

B. International level

(i) IDRC-IGFRI Silvipasture Operational Research Project.

The Government of Canada aided project is in operation at the Institute specifically for Bundelkhand region with the objective of increasing the forage and tree crop productivity on degraded lands in the region.

(ii) PL-430 Project on Weed Management Research in Food-Fodder Production System.

This project operates at the Institute with the major objectives of working out integrated weed management practices for food and fodder crop production system, evaluating herbicide residue in plants and soil and investigating the influence of these practices on the quality of produce.

TRAINING AND EDUCATION

Training:

There is a comprehensive training programme at the Institute on all aspects of forage production and its utilization. A nine month diploma course was initiated during 1976 for inservice personnel. During the year, diploma was awarded to ten candidates.

The Institute also offers short term refresher training courses for the benefit of different Govt. departments, corporations and voluntary organisation. Three candidates successfully completed the short term course. Technology appraisal training programme were also organised for farmers, village level workers, forest guards in forage crop production and raising of fuel/fodder/fruit species.
Education:

The Institute was recognised centre of research under the auspices of Jiwaji University, Gwalior, Bundelkhand University, Jhansi and Agra University, Agra for award of Ph.D. degree. Three candidates were awarded Ph.D. degree during the year.

EXTENSION

FODDER DEMONSTRATION TRIALS

During 1985, 21 adaptive demonstration trials were laid out on the farmers' fields in Hamirpur, Jalaun and Jhansi districts of Bundelkhand region. These demonstration trials on M.P. Chari+Cowpea, Maize+Cowpea, Sorghum+Guar, Bajra+Guar and Sorghum+Cowpea were conducted with the help of State Development Departments. During kharif 1985 fodder demonstrations on M.P. Chari+Cowpea and Bajra+Cowpea were conducted on farmers' fields in the vicinity of the Institute. Similarly, in the Rabi season 56 fodder demonstrations of improved Berseem and Oat varieties were laid out on Institute to Ambabai Road and Jhansi Balaji Road.

EXHIBITION

The Institute's Technological Exhibition Stall was erected in the Bundelkhand Vikas Pradarshni organised by the Zila Parishad Jhansi from 26th January to 27th February 1985. A 'Kisan Divas' was also organised in collaboration with the State Department of Animal Husbandry on 9th February, 1985 in the Exhibition in which more than 603 cattle owners participated.

SEMINARS/SYMPOSIA/WORKSHOPS/SUMMER INSTITUTES

During the year 1985 following Workshops/Seminars/Symposia/Summer Institutes were organised at the Institute:

1. Jointly organised workshop with NABARD on Dryland Farming for Bundelkhand Region during April 9-12, 1985 at IGFRI, Jhansi.
2. Summer Institute on Recent Advances in Forage Breeding for farming system held at IGFRI, Jhansi from May 6-25, 1985.

3. Group meeting of All India Coordinated Research Project on Forage Crops on June 11-12, 1985 at IGFRI, Jhansi.

4. XI Annual workshop of All India Coordinated Research Project on Forage Crops from 27-29th September, 1985 organised by All India Coordinated Project for Research on Forage Crops, IGFRI, Jhansi at APAU, Hyderabad.


STAFF

The Institute had a sanctioned strength of 237 scientists, 148 technical, 92 administrative 178 supporting and 38 auxiliary staff. The staff position as on 31-12-85 has been given in Appendix-1.

FINANCE

During the year 1985-86 the Institute has utilized a budget of Rs. 108.59 lakhs of which Rs. 14.65 lakhs was under plan and Rs. 93.94 lakhs under non-plan. The capital expenditure was Rs. 6.57 lakhs. A revenue of Rs. 3.33 lakhs was realised from the sale of farm produce. The headwise expenditure details are given Appendix-2.

FACILITIES

(i) Experimental Farm

The Institute has a total land area of 574 hectares including campus. The experimental farm has been divided into blocks earmarked for different divisions. Tar road was completed from one to the other end at farm. Additional irrigational facilities were created, although a seasonal canal runs across the farm. The farm has varying topography and represents rakar, parwa and kubar types of Bundelkhand soils.
(ii) Administrative Wing and Research Laboratories

The building complex comprises Director's office, conference hall and committee rooms with telex and telephone facilities. There are five laboratory wings with a total of 25 laboratories and 51 sitting rooms equipped with modern instruments, fixtures and furnaces. Since the Institute has multidisciplinary divisions, a separate central laboratory provides Centralised Instrumentation Services and Central Analytical Laboratory undertakes chemical analysis. Modern outfits for cartography and audio-visual aids have been provided.

(iii) Library

Due to expanded activities in the field of research, extension and training, the corresponding expansion in the library has been made. About 30 (Scientific-Cum-Other) disciplines have been covered for references on which literature was obtained within the country and abroad. During this year, library had a total of 4673 technical books, 100 Indian and 100 foreign journals for the benefit of the scientists. The library was further enriched by adding 300 reprints of scientific papers. The library is also having micro-film reading facility.

(iv) Photography and Art Unit.

The photography and art unit is functioning at the Institute to provide facilities for photography slides with respect to the field and laboratory research work. The art section prepares requisite charts, maps, etc, for scientific purposes.

(v) Scientists Home and Post Graduate Hostel.

A 13 room hostel with dining room, reading hall exists at the campus for trainees. A 5 suit scientists home is also attached with it especially for scientists and other dignitaries visiting the Institute.

(vi) Residential Complex

The residential complex known as Krishi Nagar consists of 132 quarters of various categories in the walled area of the campus. These quarters are provided with modern living amenities.
(vii) Community Centre

The Institute has a Community Centre in the residential area with necessary infrastructures for providing a better social life to the residents.

(viii) Medical Unit

The medical unit is located in the premises of the Institute with a Junior Medical Officer and other auxiliary staff to provide health care to the staff and their families.

(ix) Primary School

There is Govt. aided primary school in the campus to cater to the need of children education upto primary level to the residents of Krishi Nagar as well as to the neighbouring villages.

WEATHER

The year 1985 experienced 1140.9 mm rainfall in a well distributed 48 rainy days. The onset of monsoon was on 27th standard week and continued till the end of October. The late withdrawal of rains helped in sowing of winter crops in dryland areas. The crop growth in both Kharif and Rabi seasons was good. The highest maximum temperature was recorded 46.1 °C during the month of May.
Table—1: Temperature, relative humidity and rainfall during 1985

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature in °C</th>
<th>Relative humidity %</th>
<th>Rainfall in mm</th>
<th>No. of rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
<td>Period I</td>
<td>Period II</td>
</tr>
<tr>
<td>January</td>
<td>26.7</td>
<td>—</td>
<td>81</td>
<td>41</td>
</tr>
<tr>
<td>February</td>
<td>31.5</td>
<td>9.8</td>
<td>69</td>
<td>25</td>
</tr>
<tr>
<td>March</td>
<td>37.8</td>
<td>15.2</td>
<td>62</td>
<td>24</td>
</tr>
<tr>
<td>April</td>
<td>43.2</td>
<td>17.8</td>
<td>53</td>
<td>22</td>
</tr>
<tr>
<td>May</td>
<td>45.2</td>
<td>24.8</td>
<td>45</td>
<td>18</td>
</tr>
<tr>
<td>June</td>
<td>44.4</td>
<td>27.2</td>
<td>51</td>
<td>19</td>
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<tr>
<td>July</td>
<td>35.1</td>
<td>20.7</td>
<td>68</td>
<td>36</td>
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<td>August</td>
<td>33.6</td>
<td>25.5</td>
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<tr>
<td>September</td>
<td>31.6</td>
<td>23.4</td>
<td>87</td>
<td>60</td>
</tr>
<tr>
<td>October</td>
<td>33.3</td>
<td>20.9</td>
<td>82</td>
<td>43</td>
</tr>
<tr>
<td>November</td>
<td>28.8</td>
<td>12.1</td>
<td>84</td>
<td>42</td>
</tr>
<tr>
<td>December</td>
<td>24.3</td>
<td>7.4</td>
<td>81</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
RESEARCH HIGHLIGHTS

PLANT IMPROVEMENT

1. Six out of 8 species of grass viz., Brachiaria brizantha (IG 85-1817), Eragrostis curvula (IG 85-1822), Setaria sphacelata cv. Kuzungula (IG 85-1824), Setaria sphacelata cv. Narok (IG 85-1825), Urochloa balboides (IG 85-1827) and Urochloa mosambicensis (IG 85-1828) showed increased germination with increased diurnal temperature fluctuation. Associability studies indicated that siratro (Phaseolus atropurpureus) promoted better growth of Chloris gayana. The biomass production of mixed stand was higher than that of monocultures. In monoculture stands, legume productivity was higher than that of grass. The increase in period of cutting interval was favourable to productivity.

2. The existing gene pool of cultivated legumes was enriched by adding more than 405 cultivars. On the basis of green matter and dry matter production potential, 37 cultivars of guar (Cyamposis tetragonoloba) and 23 of moth bean (Phaseolus aconitifolius) were found promising. Germplasm of Indigofera spp. (42), Desmodium spp. (72), Phaseolus spp. (24), Macroptelium lathyroides (9), Stylosanthes spp. (19), Neonotina wightii (4), Clitoria ternatea (56), Atylosia spp. (63), Canavalia spp. (2) were added to the gene pool and studied for fodder and seed yield potential. Among Atylosia spp., A. clavicula gave the maximum fodder and seed yield. The accessions of winged bean had very poor growth under Jhansi conditions. Thirty-three spineless cultivars of safflower were identified promising.

3. Directional selection for culm and leaf characters in segregating generations of the crosses, 2219 A X Trudan, 2219 A X S-1043 in sorghum proved to be effective and the promising progenies have been earmarked. Promising progenies derived from a 3 way cross (296 A X pc-40) X 1S-2887 in sorghum were identified for further exploitation. Eight genotypes of Cenchrus Ciliaris showing fairly good tolerance to
5. In the existing germplasm of *C. ciliaris*, nine were found to be autotetraploid \((2n=36)\) and 2 cultivars showed aneuploidy of the pentaploid complement with chromosome number \(2n=44\) \((5n-1)\) and \(2n=42\) \((5n-2)\). Flowering in *S. sesban* was delayed by UV treatments. Intergeneric hybridization between *Atylosia cajanifolia* and *C. cajan* revealed chromosome homology between the species of two different genera. \(C_3\) progeny of induced tetraploid of *S. tetraptera* was characterized by high multivalent frequency and low seed set. Haploids in *S. aegyptica* revealed that there were no intragenominal homologies and 6 is the basic number for the genus.

6. Among the growth retarding chemicals, B-nine was found to be more effective for inducing drought tolerance in bajra plants. CCC reduced the lodging intensity in cats and increased the seed yield considerably. Cowpea variety HFC 42–1 was found to be salt tolerant. Calcium chloride \((40-120 \text{ m.e./l})\) increased the germination percentage of berseem whereas sodium chloride and sodium sulphate \((120 \text{ m.e./l})\) reduced the germination considerably.

7. Sorghum cultivar IS–18758 was observed symptom free with respect to anthracnose. Among \(F_1\) hybrid \((bajra \times P. orientale)\), \(P. orientale\) and back crosses \((\text{BC}_1\text{ and BC}_2)\), eight plants were observed moderately free of ergot symptoms whereas nine plants were found free of rust symptoms. These plants will be screened artificially to confirm their resistance against the respective pathogens. To control the ergot disease of bajra, the plants sprayed with 8-Hydroxyquinoline (8-HQ) without inoculation of disease showed no disease symptoms under field conditions at 100, 200 and 300 ppm concentrations. A relation between rust of *Albizia* and environmental factors.
was established. It was observed that less rainfall and less number of rainy days favoured the maximum periodical increase in number and size of the pustules.

8. The alfalfa leaf disk bioassay for feeding, by lucerne weevil (Hypera postica) indicated that fructose, glucose, galactose and maltose acted as a feeding stimulant. In sorghum the lines showing least damage of shootfly (Antherigona soccata) were IS 313, 3149, 3234, 3243, 3265, 3274, 3283, 3295, 3315, 3327, 3338. The promising material of sorghum showing moderate resistance to sorghum midge (Conterinia sorghicola) were IS 703, 704, 969, 10710, 3199, 3203, 3230, 3237, 3248, 3252, 3265, 3283, 3312, 3313 and 3341 and the observations indicated that the early flowering lines generally escaped the midge damage while damage progressively increased in late flowering types.

9. Combined effect of Eusarimum oxysporum and root knot nematode (Meliodogyne incognita) caused greater severity of disease in Sesbania grandiflora seedlings than with either pathogen alone. Thirteen annual species of Medicago showed a wide variability in their susceptibility to the root-knot nematode. M. littoralis was found to be resistant, while M. scutellata, M. intertexta and M. truncatula were moderately resistant and rest of the species were susceptible. The population densities of different nematodes were influenced by different cropping sequences. Monoculture of certain legumes, viz. Clitoria ternatia and lucerne brought considerable increase in the populations of root-knot and reniform nematodes. Cowpea and moth bean were also found susceptible for these nematodes. Grasses increased the population of some important ectoparasitic nematodes. Siratro, a poor host for root-knot nematodes, can be used in crop rotation. Meloidogyne sp., Heterodera sp., Pratylenchus sp., Tylechorynchnus sp., Helicotylenchus sp., Hoplolaimus sp., Paratylenchus sp., Ziphinema sp., Longidorus sp. Stunt nematode, (Tylenchorhynchus vulgaris) are the prominent nematode species in silvopastoral systems.

AGRONOMY & SYSTEM SYNTHESIS

1. Studies on Winter maize (pratap selection) revealed that a seed rate of 80 kg/ha recorded significantly higher green fodder (483 q/ha) and dry matter (115.4 q/ha) yields over 40 kg/ha seed rate (417 q/ha and 99.7 q/ha green fodder and dry matter yields, respectively). The yield differences due to spacings (25 and 40 cm) were found to be non-significant.
2. Maximum forage yield in turnip was recorded with 5 kg/ha seed rate (472 q/ha green fodder and 42.2 q/ha dry matter) consisting of 255 q (18.8 q D. M.) leaves and 217 q (23.9 q/ha) roots.

3. Under agro-forestry system, wheat variety Raj 1555 gave the best performance (45.95 q/ha grain yield) followed by WH 147 (42.95 q/ha). Under open canopy system, WH 147 (47.29 q/ha) and Raj 1555 (47.12 q/ha) wheat varieties were second and third in ranking.

4. Multicutt fodder sorghum pioneer hybrid (988) registered maximum productivity (sown during July for two cuts) with the application of 90 kg N/ha and keeping a seed rate of 50 kg/ha.

5. Under rainfed conditions, maximum green fodder (337 q/ha) and dry matter (81.8 q/ha) yield was obtained in fodder sorghum pioneer hybrid when cut at milk stage.

6. Maximum green fodder (296 q/ha) and dry matter (63.8 q/ha) yield was registered with mixed cropping of Stylo (6 kg/ha) and pearl millet (10 kg/ha) under rainfed conditions.

7. Relay intercropping studies in maize and cowpea revealed that planting cowpea two weeks before the sowing of maize in a paired row system resulted in maximum green fodder (237 q/ha) and dry matter (41.5 q/ha) yield with LER 1.47.

8. Maximum green fodder and dry matter yield was registered with planting hybrid napier IGFRI-3 and leucaena (K-8) in 1:1 ratio (row arrangements).

9. Under an agroforestry system maximum monetary benefits was obtained with pure planting of hybrid napier followed by pure planting of guinea grass and S. grandiflora (fuel tree) + hybrid napier.

10. Mixed cropping of cowpea N. P. 3 (broadcast sown) at the rate 20 kg/ha super-imposed by 25 cm apart row crop of Deenanath grass yielded maximum fodder yield.

11. Planting oat (IGFRI-S-3021) in rows mixed with lucerne (IGFRI-S-244) as broadcast resulted in maximum productivity.

12. Crop geometry studies in fodder sorghum hybrid (988) and Cowpea (HFC 42-1) revealed that planting cereal and legume components in 1:1 ratio (paired row
system) with 50 percent higher than the normal seed rate used under mixed cropping proved to be the most remunerative treatment combination in terms of forage yield.

13. Oat variety JHO-816 appeared to be very promising and needs irrigation at IW/CPE ratio of 1:1 to provide suitable moisture environment for higher herbage production. Substituting every 4th row with mustard was as good as regular rows of oat at 25 cm spacing but required irrigation at IW/CPE ratio of 0.8 to effect water economy.

14. Among lucerne varieties evaluated, IGFRI-244 held promise for higher green forage yield. The irrigation schedule in lucerne should consist or irrigating the crop at IW/CPE ratio of 1.0 to provide optimum conditions for greater herbage accumulation.

15. Berseem, IGFRI-99-1 (Wardan) produced the highest green and dry matter yields as compared to BL-I and JB-1. The crop needs irrigation at 45 mm. CPE with 60 mm. water for achieving higher productivity and rationalizing water use.

16. Sorghum varieties HD-2 and Pioneer possess the potential for high herbage yield and maintenance of soil moisture at 75% ASM is required to obtain increased yield of succulent forage.

17. Bajra crop needs to be maintained under super optimum level of soil moisture during establishment and vegetative growth phases. Soil moisture at optimum and sub-optimum levels may, however be considered during reproductive stage to effect water economy in forage production.

SOIL SCIENCE

1. The intercropping of napier-bajra hybrid with berseem, sunhemp and cowpea increased the forage yield by 25% over pure cropping of napier-bajra hybrid apart from building up soil fertility. Intercropping of napier-bajra hybrid with different legumes indicated that the P use efficiency was almost doubled when P was applied to berseem during winter season. Further, the higher rate of P increased the availability of N and P. Higher N use efficiency was observed with the application of organic and inorganic sources on 50:50 basis. Amongst different cakes, mahua cake found to be the best.
The intercropping system raised the productivity of crops (cereal + legume) over sole cereal crops. Application of P of equivalent area basis is necessary for achieving higher yield. Application of S @ 40 kg/ha increased the yield of chinese cabbage under dryland condition.

2. The forage and grain yields of bersey increased when the crop was preceded by legume crops like cowpea and sunhemp. The yield advantage was to the tune of 3–4.7 q/ha in terms of dry forage. The benefit in grain yield was equivalent to the yield obtainable with 30 kg N/ha. The contribution from cowpea as green manure crop was observed to be 35 kg N/ha against 13 kg N/ha from forage cowpea. The highest forage yield was obtained when the crop rows were in the direction of SE–NW. The yield increase ranged from 14–20% over other directions.

3. Amongst the different crops tried under tree canopy, lucerne was found to be most productive crop yielding about 77% green forage of non-tree situation. In terms of seed yield, gram, pea, barley and lucerne reduced 67, 44, 42 and 16% of open allowing about 80% PAR under Albizia lebbek. Silvipastoral studies indicated strong tree–grass interaction. At 60–65% PAR level Albizia lebbek was found to be the most productive system yielding at par with open grasslands and significantly out-yielded the Albizia procera and Accacia nilotica. The soil fertility build up was significantly higher with Leueana leucocephala and Albizia lebbek.

4. The productivity of crops was found to be poor in calcareous soil with CaCO₃ nodules ranging from 15–20%. The winter maize varieties gave about 13.0–26.7 q/ha of dry forage. Manjari composite, however, yielded 26.7% q/ha dry forage and 11.9 q/ha of grain. In such soil cowpea varieties UPC-9805, UPC-9030 and UPC-5286 gave 34.3–36.7 q/ha of dry forage. The crop responded upto 26 kg q/ha. Mo application @ 1 kg MoO₃/ha increased the dry forage yield by 13%. Puddling in calcareous loamy sand helped in increasing the available P and thermal regime of soil at sowing. This in-turn increased the yield of lucerne by about 18% over normal tillage practice. Under acid soils with PH ranging between 5.1–5.2, the cowpea variety UPC-9805 gave highest yield and responded to 80 kg P₂O₅/ha. Amongst winter maize varieties, manjri composite gave the highest dry matter yield (36.6 q/ha) and was significantly superior to other varieties. Maize also responded to 80 kg P₂O₅/ha.

5. Lucerne (Anand–2) and cultivar of berseem (Wardan) were found to be the most compatible genotypes with respect to Rhizobium for attaining higher forage production. Better
genotype compatibility of giant bajra, M. P. Chari and Manjri composite maize
was noticed with *Azospirillum brasilense*. The increase in fodder yield of oat by seed
inoculation with *Azospirillum* + 40 kg N/ha was comparable to 60 kg fertilizer N/ha
alone indicating there by a saving at 20 kgN/ha. Similarly, inoculation of *Azotobacter chroococcum* revealed saving of about 15 kg N/ha in M. P. Chari. Subabool leaf
manuring (5.1% N) upto 5 t/ha along with *A. brasilense* exhibited positive effect on
forage yield of sorghum. Application of 20 kg Zn So₄/ha in *Centrosema pubescens*
and 10 kg S/ha in *Desmodium tortusum* and *Stylosanthes humilis* were found red soil
to maximize the efficiency of pasture legume-Rhizobium symbiotic system. Phosphorus at 60 kg P₂O₅/ha was found to be optimum for Rhizobial inoculated
*Leucaena leucocephala* (var-K-8). Seed inoculation with phosphate solubilizers (*Pseudomonas stricta* and *Bacillus polymixa* H₆) increased the forage yield of rock phosphate
fertilized oat and M. P. Chari.

**GRASSLAND MANAGEMENT**

1. In the five species of *Stylosanthes* and four grasses viz., *Dichanthium annulatum*
*Cenchrus ciliaris*, *Cenchrus hybrid* and *C. setigerus* maximum establishment was obtained when sown at a depth of 1.2 cm in legumes and at 0.8 cm in grasses. The 16kg/ha seed rate gave maximum population establishment in *Cenchrus hybrid* and *C. setigerus*, however, the maximum forage production was obtained with 12 kg/ha seed rate in *Cenchrus hybrid* and 16 kg/ha in *C. setigerus*. The experiments on suitable methods of sowing and planting material in both the *Cenchrus* species revealed the superiority of broadcasting method for higher establishment and forage production compared to line sowing.

2. Studies on the effect of different management pratices on the productivity of *Dichanthium annulatum*, *Cenchrus ciliaris*, *Cenchrus hybrid*, *Cenchrus setigerus* in pure stands as well as mixtures with *Stylosanthes hamata* revealed that the dry matter yield obtained with application of 60 kg N + 30 kg P₂O₅/ha with or without interculture was at par in all the grasses when grown alone or in mixed stand. However, the forage yield was significantly higher as compared to that of the control. The studies on application of fertilizers and intercropping of legumes with and without fertilizers in
Chrysopogon fulvus, Setaria sphacelata, Brachiaria brizantha, Panicum coloratum, P. maximum showed maximum forage yield with the intercropping of legumes along with the fertilizers as compared to that of the pure stand with and without fertilizers.

3. Out of the four legumes tried for introduction in Eremopogon foreolatus dominated grasslands Atylosia scarabaeoides showed the highest establishment counts (44583 plants/ha), followed by siratro (33333/ha). The maximum mixed dry forage yield (37.49q/ha) was obtained with the exotic legume, Siratro, followed by that of S. hamata. Line sowing in June proved to be the most suitable for introducing the legume S. hamata in natural Heteropogon dominated grasslands.

4. The Mandya sheep grazing on mixed stands of Dichanthium with S. hamata maintained their body weight for longer duration with higher body weight gain compared to the pure stands. In the mixed pastures of C. ciliaris+S. hamata heifers recorded a weight gain of 386 g/head/day as compared to 203 g/head/day when maintained on pure C. ciliaris sward for 52 days. Further in the natural grasslands, the body weight gain of 101 g/head/day was recorded in Haryana heifers in 57 days grazing. The spear grass pastures harvested every 60 days recorded 66.0 g/ha production.

5. In the natural Sehima-Heteropogon community under controlled grazing treatments showed higher than vigour compared to plots harvested manually. Eighteen ecotypes of Cenchrus ciliaris and fourteen races in case of naturalised legume Stylosanthes hamata were identified during the field studies on the basis of their morphological characters and transplant expression. Among the thirteen ecological races of C. ciliaris tried in mixture with Stylosanthes hamata cv. verano in 1 : 1 ratio, C. ciliaris cv. JGFRI-3108 was identified to be most suited for mixed pasture. In Chrysopogon fulvus the fertilizer had more pronounced effect on stem as compared to the leaf component. In Cenchrus spp., the seeds can be stored safely for 12-24 months in polythene and paper bags after which their viability was found to decrease.

AGRO-SILVIPASTURE

1. The selection (Silvi-4) from L. leucocephala out yielded 11 diverse and elite varieties. It has shown higher diameter increment in coppice shoots.

2. A highly branched type of [Sesbania sesban has been identified for higher biomass production on marginal lands.
3. One of the interspecific hybrid of *L. leucocephala* and *L. pulverulenta* was better than K-8 and K-28. In *L. leucocephala* (F$_2$ generation) some crosses of peru X Salvador types appeared better than K-8 in fodder and fuelwood production.

4. In initial testing of multipurpose tree germplasm, *Acacia pennatula* has been found to be promising for calcareous marginal soils.

5. In summer fellings of *L. leucocephala* the dry matter distribution was almost same from base to the tip of the bole. The bark contained higher moisture content. The litter production studies on 10,000 plants/ha density indicated peak litter production value during April (131.4 g/m$^2$).

6. Optimum range of temperature requirement for better seed germination was standardised. Seeds of *Albizia amara* and *A. lebbek* preferred comparatively lower temperature regime with considerable temperature fluctuations. The seeds of *A. procera* preferred relatively higher temperature regime with moderate temperature fluctuations. Germination in *D. cinerea* occurred over a wider range of temperature regimes and fluctuations.

7. The red light stimulated seed germination and early seedling vigour of *A. lebbek* and *A. procera*. The infra red light reversed the effect of red light to some extent.

8. 10-15 ppm GA solution and 50 ppm L-AA solution stimulated seedling growth in *A. lebbek* and *A. amara* respectively.

9. *Cenchrus* pasture was successfully re-established in a stand with 200-250 trees of *A procera* / ha. The pasture gave an annual dry yield of 2.25 t/ha in the very first year.

10. In a silvipastoral trial with *Acacia nilotica* and *A. tortilis*, the alternate plant arrangement gave better growth of both the species in mixed plantations.

11. In Agro-silvi-forage production studies certain systems viz. Jowar-subabul-shevari and Jowar-cowpea-subabool-shevari were identified to produce 13.2 & 43.6 t/ha dry matter under rainfed and irrigated situations respectively.

12. The guinea grass based forage forestry system with *L. leucocephala* gave almost double yield as compared to sole crop of each species.
13. Yearly loppings in species like *Albizia* and half yearly loppings in species like *D. cinerea* are feasible.

14. Maximum biomass from *A. tortilis* at 13th year was obtained with wider tree spacings in association with *C. ciliaris-stylo* pasture.

**SEED PRODUCTION TECHNOLOGY**

1. Application of 80 kg N/ha in the rootzone at sowing or at knee height stage is beneficial for sorghum seed production. Foliar spray of P₂O₅ (2.5 kg/ha) and KNO₃ (2.0 kg/ha) gave additional seed yield of 1.2 q/ha over control treatment.

2. Among *Panicum maximum* varieties, Gatton produced the highest seed yield. Linear response upto 120 kg N/ha was found in *P. maximum*. Planting of grasses at 50 cm ×50 cm appeared to be optimum spacing for higher seed yield of *Setaria sphacelata* and *Chrysopogon fulvus*.

3. Among three varieties of oat, IGFRI-3021 provided an additional green fodder of 115 q/ha without reducing seed yield at 60 days cut as compared to uncut crop. The introduction of cowpea @ 20 kg seed/ha in sorghum (M. P. Chari spaced at 50 cm) gave an additional 3.2–3.3 q seed and 83 q fodder without affecting the seed yields of sorghum.

4. Phosphorus uptake exhibited great association with translocation of water soluble sugar to seed during reproductive stage. This requirement of lucerne is mainly met by native soil. The efficiency of fertilizer P is increased by its split application adjusted from pre to 50% flowering stage for reaping high seed yield of cowpea.

5. Physiological efficiency (catabolic process—release of simple sugar for efficient seedling emergence and increased uptake P and N) of berseem was improved by seed hardening system of 24 hours soaking. The barley varieties for high seed yield must possess high P : R (photosynthesis : respiration > 3.0 < 5.0) with moderate dark respiration, high harvest index and leaf angle among physiological characters and number and size of ears or number of grains/ear among seed yield components.
6. Lucerne varieties required high nitrogen, high phosphorus and medium magnesium at pre-anthesis stage for potential build up of photosynthate and seed yield. Greater leaf width and low translocation distance of upper internodes favoured the synthesis of sugar and its accumulation for seed production in sorghum. Foliar application of KNO₃ (2.0 kg) and super-phosphate (1.0 kg/ha) at pre-anthesis stage augmented the physiological process (sugar synthesis and its utilization and pod retention capacity) responsible for increased seed yield in cowpea.

7. Monocrotophos (0.075%) proved best for controlling the incidences of mustard aphids and enhancing the fodder and seed yields. The application of phorate 10 G (1.5 kg/ha through soil and endosulfan) 35 EC (0.075%) sprayed at 40 and 60 days of sorghum growth left negligible amount of residues and crop can safely be harvested at 70 days for forage. However at high concentrate of endosulfan (0.1%), the crop would be safer only after 80 days of growth. Bajra varieties viz; V-61, V-824, V-821, V-63, V-815 and V-823 were found to be tolerant against shoot fly and stem borer.

8. The seed treatment with Bavistin (0.25 g–0.30 g/kg of seed) reduced the effect of anthracnose disease—Colletotrichum gloeosporiodes in Stylosanthes viscosa, S. gracilis S. scabra, S. humilis and S. hamata. It is also effective against seedling disease in sorghum and seed borne pathogens in lucerne. In berseem, however, pre-sowing seed treatment with Thiram (0.3 g/kg of seed) controls the seed borne disease and thus brings out 48–58% increase in growth and seed viability upto five years if stored in air tight plastic containers under natural conditions. In oil seed crop, the prominent seed borne pathogens (Macrophomina phaseolina, Fusarium oxysporum and Sclerotium rolfsic) caused seedling mortality and post-emergence loss to a great extent.

PLANT-ANIMAL RELATIONSHIP

1. Histochemical studies on grasses harvested at monthly intervals from August to October revealed that there was practically no lignification in leaf blades in August and that the lignified tissues increased in later months. The intensity of lignification was more in the bottom stem than in the top stem in all the cuts.
2. Evaluation of Agroforestry system of forage production comprising of hybrid napier + *Stylo* + *Sesbania* (2:1:0.5) has shown that it provided sufficient nutrients for growing calves (DCP 7% and TDN 57%).

3. Laboratory studies on treatment of five legume forages with formaldehyde (@ 1% on protein basis) showed that it reduces protein solubility significantly and this may improve utilization of forage protein.

4. Polled hair analysis and Haematological studies to determine trace mineral status in calves revealed that there was deficiency of Copper and zinc.

5. Grazing experiments on growing calves have shown that mixed pasture of *Cenchrus ciliaris* and *Stylosanthes hamata* supported better animal performance (growth rate @ 285 g/h/d), than pure *Cenchrus* pasture (growth rate 203 g/h/d) during the months of August-September.

6. Varietal evaluation of hybrid napier (NB-21 and IGFRI No. 3) for growing calves has shown that IGFRI No. 3 (90 days growth) was superior in terms of palatability and nutritional value (DCP 1.3%, TDN 48.8%).

7. Supplementation of *Leucaena* fodder to coastal Bermuda grass based ration of milch cattle (35% DM) improved the milk production by 12.5%.

8. *In vitro* studies on the evaluation of forage mixtures comprising of *Sesbania aegyptica*, *Leucaena leucocephala*, berseem and cowpea with dry grass/paddy straw/oat straw/wheat bhoosa in different proportions (25, 50, 75%) have shown that 75% of legume and 25% crop residues recorded maximum CP and IVDMD values.

9. Investigations undertaken on *Zornia diphylla*, a commonly occurring forage legume in grasslands revealed that this non-conventional forage legume did not possess any toxic principle and could be utilized as livestock feed.

10. Chemical evaluation of *Borussia stricta* seeds have shown that it is a rich source of essential as well as non-essential amino acids and essential fatty acids (Linoleic acid 61.8%). The seeds were found to be free from any toxic principles and could be incorporated in concentrate mixture.
1. The results on field method of hay making in windrows of different depths revealed significant decrease in the total moisture loss with the increased windrow depth. However, the good drying weather available in August-September was usually interrupted by rains before the product was dry enough to be stored, prolonging thereby the drying duration which tended to develop mould growth. It may therefore, be inferred that field drying of hay in the month of August-September can be taken up only when a minimum dry spell of 73 hours is expected.

2. Turning of windrow immediately after harvest exhibited significant increase in moisture loss. The moisture loss was further increased with the increase in windrow depth. The subsequent turnings, however, did not enhance the moisture loss when the moisture content in the windrow dropped down to 120 per cent d. b.

3. Hay could be made satisfactorily on all the structures despite interception of good weather frequent rainfall. The entire hay made on structures was free of apparent mould growth. The hay drying shed exhibited superiority over the other structures during the period of frequent and prolonged rainfall and followed by A-frame structure. The Tripod exhibited the minimum drying rate.

4. The loss of crude protein resulting from the chemical changes during the drying process was principally attributable to the respiration and microbial activity. The loss was observed to be proportional to the duration of the drying phase. The following expression presented the relationship between the per cent loss of crude protein CP and drying hours (h),

\[ CP = 0.376 (52.5289 + h) \]

\[ r = 0.930 \]
5. In all cases, the value of *In vitro* true dry matter digestibility (IVTDM) decreased with the decrease in CP values. However, between the treatments no significant variation in IVTDM values was observed.

6. Vegetative cover of grasses and legumes significantly reduced the run off and soil loss from natural grassland area. The run off coefficient was observed in the order of 0.07, 0.11 and 9.15 and soil loss 1.5, 2.5 and 3.6 t/ha from 3, 5 and 10% slopes, respectively.

7. The optimum energy input on hectare bases for M. P. Chari varied from 1770–1865 MJ and for oat crop 8425–8505 MJ.
DIVISION OF PLANT IMPROVEMENT

PI-1: GENETIC RESOURCE COLLECTION, EVALUATION, CLASSIFICATION, CATALOGUING AND MAINTENANCE IN FORAGE CROPS.

1.1 Range Grasses:

(S. R. Gupta and J. N. Gupta)

Two hundred eighty two new accessions of Cenchrus ciliaris (24), C. setigerus (23), Dichanthium annulatum (7), Panicum antidotale (35), Brachiaria decumbens (1), Urochloa mosambicensis (1) and other species (191) were added to the germplasm. The germination of 8 grasses was studied in alternate months in fields beds. The data (Table 2) revealed that in general, germination increased with rise in temperature from March, onwards reaching to the peak in May and gradually decreased after rains in July, probably due to decreasing difference in diurnal temperature fluctuations (DTF), was almost stable over July–September, and further lowered during November month. The reduced difference in DTF reflected remarkable similarity in germination during cool, winter months of January and November. These results indicated pronounced influence of DTF on germination.

Associability Studies:

The seeds of siratro were broadcasted in a naturally occurring Chloris gayana pasture in an area of one acre in July 1983. After the harvest of biomass, the data on regrowth was obtained between October, 83 to July, 84 as per the following treatments.

( 25 )
1. Plots with only grass (legumes and other species removed)
2. legume (grass and other species removed)
3. grass + legume

Table 2: Germination (per cent) of different grasses in alternate months.

<table>
<thead>
<tr>
<th>Species</th>
<th>Jan</th>
<th>Mar</th>
<th>May</th>
<th>July</th>
<th>Sept</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brachiaria brizantha (IG 85-1818)</td>
<td>15</td>
<td>25</td>
<td>33</td>
<td>27</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>2. Brachiaria decumbens (IG 85-1818)</td>
<td>18</td>
<td>25</td>
<td>24</td>
<td>11</td>
<td>36</td>
<td>16</td>
</tr>
<tr>
<td>3. Eragrostis curvula (IG 85-1822)</td>
<td>16</td>
<td>19</td>
<td>33</td>
<td>9</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>5. S. sphacelata cv. Narok (IG 85-1825)</td>
<td>16</td>
<td>11</td>
<td>40</td>
<td>18</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>6. S. sphacelata cv. Nandi (IG 85-1826)</td>
<td>18</td>
<td>24</td>
<td>21</td>
<td>32</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>7. Urochloa balbades (IG 85-1827)</td>
<td>27</td>
<td>34</td>
<td>60</td>
<td>33</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>8. U. mosambiscensis (IG 85-1828)</td>
<td>24</td>
<td>24</td>
<td>33</td>
<td>33</td>
<td>37</td>
<td>28</td>
</tr>
</tbody>
</table>

The harvest was taken once after 4, 12, and 16 weeks regrowth (in July, Aug, September and October). These plots were again left for regrowth of grass and legume till 16 weeks in each case. Those harvested in last week of July, August, September and October, were again harvested in the last week of November, December, January and February.
Table 3: Dry matter production kg/m² at different intervals of cutting in *Chloris gayana* pasture.

<table>
<thead>
<tr>
<th>Duration (weeks)</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>0.57</td>
<td>0.69</td>
<td>0.78</td>
<td>0.95</td>
</tr>
<tr>
<td>Legume</td>
<td>0.85</td>
<td>1.20</td>
<td>1.25</td>
<td>1.30</td>
</tr>
<tr>
<td>Grass + Legume</td>
<td>0.79</td>
<td>1.30</td>
<td>1.33</td>
<td>1.58</td>
</tr>
</tbody>
</table>

The increase in dry matter production with increasing period of harvesting appeared to be due to longer span of time available for regrowth (Table 3). The grass + legume association gave higher biomass compared to grass or legume alone irrespective of harvest interval. In monoculture, the legume production was higher than grass.

Table 4: Dry matter production kg/m² after 16 weeks regrowth of grass, legume and their association.

<table>
<thead>
<tr>
<th>Duration (weeks)</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>0.99</td>
<td>0.87</td>
<td>0.60</td>
<td>0.53</td>
</tr>
<tr>
<td>Legume</td>
<td>1.35</td>
<td>1.10</td>
<td>0.85</td>
<td>0.45</td>
</tr>
<tr>
<td>Grass + Legume</td>
<td>1.65</td>
<td>1.38</td>
<td>1.00</td>
<td>0.88</td>
</tr>
</tbody>
</table>
The production pattern after 16 weeks of regrowth again revealed that biomass was maximum for grass legume association followed by legume and grass (monoculture). Individually, legume was better than grass in yield.

This study revealed that siratro and rhodes grass have association preference, though individual component's growth is lightly affected, but overall biomass production was better in mixed stands.

1.2 Cultivated Legumes:

(U. P. Singh, J. N. Gupta and O. P. Dixit)

Guar (Cyamopsis tetragonoloba)

Two hundred forty four lines of guar (C. tetragonoloba) were grown in three replications to study its fodder production potential. Data was recorded on three randomly selected plants from each replication on various fodder attributes. The study showed wide range of variability in days to 50% flowering (30.5-58.9), plant height (39.1-119.6 cm), node number (19.1-39.6), branch number (0-17.3), branch length (7.4-74.5 cm), leaf length (2.2-10.0 cm), leaf width (1.3-6.1 cm), stem girth (2.5-8.9 mm), leaf number (10.6-111.2), green leaf wt. (1.2-62.3 g), green stem wt. (4.0-72.1 g), leaf dry wt. (0.7-16.2 g), stem dry wt (1.3-13.1 g), green matter/plant (2.5-25.4 g) respectively. The material was also classified in different groups based on frequency intervals. The promising cultivars identified on the basis of green and dry matter yield were IL 1663, 1666, 1669, 1670, 1679, 1680, 1683, 1684, 1685, 1687, 1690, 1694, 1696, 1697, 1698, 1702, 1703, 1705, 1720, 1723, 1732, 1739, 1740, 1741, 1743, 1744, 1745, 1746, 1747, 1748, 1770, 1773, 1774, 1776, 1778 and 1827.

Moth bean (Phaseolus aconitifolius)

The germplasm comprising 244 lines of moth bean were evaluated for different plant characters. Observations were recorded on three randomly selected plants from each replication. A wide range of variation was observed for various parameters, viz., days to 50% flowering (31.0-57.3), plant height (21.9-123.0 cm), node number (13.8-25.0), branch length (22.4-119.8 cm), green yield/plant (13.6-259.0 g), dry matter yield/plant (3.5-45.0 g) and dry matter percentage (10.0-28.0%). Out of these, JLO 63, IL 1031, 1037, 1038, 1042, 1043, 1057, 1050, 1060, 1061, 1064, 1066, 1072, 1074, 1076, 1077, 1102, 1111, 1127, 1132, 1180 and 1202-3 were identified promising.
1.3. Range Legumes:

(J. N. Gupta, S. R. Gupta and U. P. Singh)

One hundred and two new accessions of different range species were added to the gene pool. The germplasm of Indigofera spp (42), Desmodium spp (72), Phaseolus spp (24), Macroptelium lathyroides (9), Macroptelium atropurpureum (7), Stylosanthes spp (19), Neonotionia wightii (4), Clitoria ternatea (56), Atylosia spp (63), Canavalia spp (2), was evaluated for different growth parameters. In Indigofera spp., wide range of variation was recorded in plant height (44.4-131.0 cm), branch number (2.7-129.7) and fresh weight/m² (0.91-7.14 kg) in three cuts. The majority of accessions either remained dormant or showed poor growth during the winter season. I. confusa, I. sumutrana, I. tetlensis and I. semitrixijuga were observed better forage type and the data indicated that these could be exploited for forage production.

Table 5: Variability in plant height, branch number and fodder yield of Indigofera spp.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Range of variation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>cm</td>
<td>44.4-70.0</td>
<td>70.1-90.1</td>
<td>90.1-110.0</td>
<td>110.1-131.1</td>
</tr>
<tr>
<td></td>
<td>(cm)</td>
<td>(9)</td>
<td>(13)</td>
<td>(6)</td>
<td>(3)</td>
</tr>
<tr>
<td>Branch Number</td>
<td>2.7-9.0</td>
<td>9.1-15.0</td>
<td>15.1-21.0</td>
<td>21.1-29.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(cm)</td>
<td>(11)</td>
<td>(8)</td>
<td>(7)</td>
<td>(5)</td>
</tr>
<tr>
<td>Fresh wt kg/m²</td>
<td>0.91-2.50</td>
<td>2.50-4.0</td>
<td>4.00-6.50</td>
<td>6.50-7.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(cm)</td>
<td>(18)</td>
<td>(5)</td>
<td>(6)</td>
<td>(2)</td>
</tr>
</tbody>
</table>

No. of accessions falling in each class (in parenthesis)

Among Atylosia complex the maximum fodder and seed yield was recorded in A. albicans followed by A. scarabaeoides, A. platycarpa and A. sericea. A wide range of vari-
ability was observed in different characters. Fresh wt/plant ranged from 8.5 to 870.0g. Minimum fresh wt in *A. platycarpa* and maximum in *A. albicans* was recorded. A marked range of variability in different characters of *Clitorea ternatea* was also recorded for plant height (30.0-71.4 cm), number of nodes (11.5-27.3), number of branches (6.6-13.11), branch length (40.4-73.2 cm), dry weight/plant (5.3-23.0g) and leaf:stem ratio (0.52-3.65). Forage production potential in 19 accessions of five *Stylosanthes* species ranged from 1.263 kg to 4.526 kg/m² per year (in three cuts).

Fourteen cultivars of winged bean (*Psophocarpus tetragonolobus*) grown in red sandy soil exhibited very poor growth. It was also noticed that their moisture requirement was much more than other legumes being grown in this region.

1.4 **Other Forage species**:

(J. N. Gupta, U. P. Singh and O. P. Dixit)

The germplasm comprising 137 cultivars of *Carthamus tinctorius* and 240 cultivars of *Brassica* species were evaluated during the year. *Carthamus tinctorius* cultivars were evaluated under rainfed condition. A remarkable variation was recorded in days to 50% flowering (121-138), plant height, (39.2-171.3 cm), node number (28.0-53.7), number of branches (3.7-18.6), fresh wt. of leaves/plant (10.7-90.7g), fresh wt. of stem/plant (35.0-280.3g), Dry wt. of leaves/plant (3.3-17.4g), Dry wt. of stem/plant (5.7-65.7g) and spininess. There was observed a considerable range of variation in different forage and seed characters in 240 collections of *Brassica* species for days to flowering (38-66), plant height (59.2-245.6 cm), number of nodes (27.6-95.3), number of branches (4.3-30.0), length of largest branch (42.4-168.9 cm), total siliqua on main shoot (18.6-211.3), number of seeds/siliqua (8.6-168.0), fresh weight/plant (31.6-740.0g), dry weight/plant (10.0-114.6g).

**PI-2 : BREEDING VARIETIES OF CULTIVATED NON-LEGUMINOUS FODDERS.**

2.1 **Production and quality breeding in fodder sorghum** (*Sorghum bicolor*)

(D. S. Katiyar)
One hundred and six accessions were evaluated along with two controls i.e. HD₁ and HD₂ for growth habit, insect-pest incidence and 50% flowering. Wide range of variability in the material was observed. On the basis of no of eggs, no of dead hearts and injury to plant, lines I. S. 3113, 3114, 3234, 3243, 3285, 3274, 3283, 3295, 3315, 3328, 3337 were found moderately resistant to shootfly.

Screening of the material for sorghum midge (*conterinia sorghicola*) resistance indicated that the early flowering lines, in general, escaped the midge damage.

F₂ populations of the crosses (i) 1328 × OP, (ii) MPC × RIO, (iii) MPC × OP were raised and observations on growth fifteen F₆ progenies of the cross RIO × HD₁ were raised.

2.2 : Intra and interspecific hybridization in sorghum

(Bhag Mal and U. S. Mishra)

1. Evaluation of F₅ Progenies

Twenty three selected F₅ progenies of ten crosses obtained through continued pedigree selection were studied to estimate the effectiveness of directional selection for culm and leaf characters. Thirty four entries (23 progenies and 11 parents) were evaluated in a randomized block design with three replications. Observations were recorded on ten randomly selected plant for height, culm thickness, leaf number, leaf length and leaf breadth.

The results indicated differential effect of directional selection in different crosses. The progenies showing remarkable effect of directional selection were recovered from the crosses, viz., 296 A × M.P. chari and 2219 A × IS-4770 for plant height, 2219 A × Trudan, 2219 A × SSG 59-3 and 2219 A × C-102 and 2219 A × S-1043 for leaf breadth. Thick stem types were obtained from the cross 2219 A × IS-4770 and 2219 A × S-1043 while the thin stem types belonged to the cross 2219 A × J-69 and 2219 A × SSG 59-3. None of the progenies showed effective improvement of leaf number.

2. Advancing of hybrid generations

(i) F₂ generation 24 crosses were raised and 212 single plants from different crosses were selected and their seed harvested to raise plant-to-row progenies next year.
(ii) Four hundred nineteen F₃ progenies derived from 95 crosses were raised in single rows and evaluated for various characters. The inferior progenies were discarded and 405 promising plants from progenies were selected to raise F₄ generation.

(iii) Fourteen promising progenies derived from a three-way cross (296 A x PC-40) x IS-2887 were raised. Twenty three promising single plants were selected from these progenies for advancing to F₄ generation.

(iv) Ninety two F₄ progenies were raised and studied. Seventy promising single plants from promising progenies were selected for further advancement and the rest were discarded.

(v) Seventy five F₅ progenies were raised and ninety seven promising single plants from promising progenies were selected to raise F₆ generation.

(vi) Seventeen plants were selected from the selfed generation of BC₁ of three crosses, viz., 196 A x SSG 59-3, 296 A x M-35-1 and 296 A x M. P. Chari and BC₂ of the cross 296 A x PC-40.

2.3 : Production and quality breeding in fodder oats (Avena Sativa L.)

(R. N. Choubey and S. K. Gupta)

1. Screening of new germplasm

Fifteen varieties of spring oats procured from Mexico were sown for initial screening with respect to various forage attributes. The varieties viz., Nodaway, Paramo and Diamante appeared to be suitable for forage production. The variety Diamante was late flowering type while Paramo and Nodaway were early types.

2. Hybridization and handling of segregating progenies

Hybridization was attempted at intervarietal and interspecific level so as to recover superior recombinants. Forty five crosses were attempted at intervarietal level. Interspecific hybridization programme included crossing of diploid A. strigosa with tetraploid A. magna and hexaploid A. sativa so as to synthesize new gene pool complexes at higher ploidy levels.

(32)
The variety Hiugo Karyokuro, an excellent donor for high regeneration capacity was extensively utilised in crossing to develop genotypes suitable for multicut. Other parental line suitable as forage types, viz., Pennline, Pennlo, PA8224, PA8244, Zenshi and Akiyutaka were also utilized in crossing programme.

The F₁ hybrids synthesized during rabi 1984 were sown in rabi 1985 with their parents so as to determine the true nature of the hybrids and the pattern of dominance of the characters. The selfed plants present among the hybrids were discarded. The segregating progenies of various oat crosses were handled under two major methods of breeding i.e. Pedigree method and Single seed descent method.

Among many F₂ crosses grown, the crosses viz., (PA8244 × OS-7), (PA 8224 × 67-22), (OS–6 × PA 8224) × (UPO-94 × IGO-320) and (200–50 × JHO-802 × OS–6), exhibited high variability useful for selection of elite plants. These crosses also indicated that the parent have nicked well. Single plants selected in F₂ will be advanced to F₃ families during rabi 1986.

The F₂ elite plants of different crosses selected during rabi 1984 were sown in 1985 to raise F₃ under single seed descent method. Selection will be avoided till the desired level of homozygosity is achieved. Some of the F₂ crosses grown in 1984 were bulked to raise F₃ during the current year.

The material in F₄ generation was raised in single seed descent fashion with no selection pressure. However, the population in F₅ will be subjected to selection during rabi 1986. The Progenies in F₅ generation were subjected to high selection pressure so as to obtain desirable progeny/plant. In addition, superior single plants available in the inferior families were also selected.

Introgression of useful genes from wild species:

Wild Avena species such as A. sterilis and A. magna possess many desirable forage attributes, viz; better tillering, quick regeneration and high protein content in comparison A. sativa were used in the interspecific gene transfer programme initiated during 1980-81 and the array of genetic material was generated and raised.

(A) A. sativa × A. magna :

(i) 7 decaploid progenies in C₂ generation,
(ii) 3 progenies in BC$_1$,

(ii) 4 progenies in BC$_1$ F$_2$,

(iv) 2 progenies in BC$_2$. The C progenies comprising of three crosses of A. magna with A. sativa genotypes, OS-6, UPO-94 and JHO-801 exhibited a high level of uniformity with respect to various plant characteristics. The plant will be analysed for their seed fertility and chromosome numbers.

Other BC$_1$ F$_2$ and CB$_2$ progenies with different ploidy levels will be analysed for fertility and chromosome stability so as to recover desirable genotype possessing the traits of both A. sativa and A. magna.

(B) A. sativa x A. sterilis :

(i) 2 progenies in EC$_1$ generation,

(ii) 6 progenies in BC$_1$F$_2$ generation. Three A. sativa genotypes, OS-6, PO-3 and UPO-94 were crossed with A. sterilis so as to obtain F$_1$ S with different genetic background. In each single cross and back cross generation, several F$_1$ plants were backcrossed and also selfed to produce a population of back-cross derived (BC$_1$F$_2$) lines. Elite plants of interest will be selected to synthesize populations of advance generations subsequently from 1986 onwards. Desirable plants will be selected from each generation.

Development of new strains :

Based on the performance of newly bread oat selections developed through inter-varietal hybridization in preliminary and advanced varietal trials, four new strains, JHO-831, JHO-832, JHO-833 and JHO-834 were identified for further testing under All India Co-ordinated Forage Project.

Multi-locational testing of varieties under All India Co-ordinated Forage Project :

Five newly developed strains were identified for further testing in initial evaluation trials (IET) under all India co-ordinated forage project.
Multiplication of Oat strains:

The promising strains, viz., JHO-813, JHO-816, JHO-817, JHO-822, JHO-825, JHO-826, JHO-827, JHO-828, and JHO-831 were sown for their seed increase.

2.4 Development of high yielding and nutritive varieties of fodder bajra.

(S. K. Gupta and R. N. Choubey)

Stabilization and evaluation of new populations:

Twenty-three populations of pearl millet developed during the last four years were subjected to cluster bagging so as to allow intermating and stabilization of gene frequencies. Undesirable plants were rogued out and efforts were made to make these populations uniform plant height and flowering time. Four populations i.e., JFB-801, JFB-817, JFB-821, and JFB-822 were grown for seed multiplication.

Initial yield evaluation:

In an initial evaluation trial, the performance of JFB-817, JFB-821, JFB-822, and JFB-843 was compared with other pearl millet populations. It was observed JFB-822 and composite excelled all other varieties for green fodder yield and dry matter production, respectively. JFB-843 also exhibited a promising performance.

Advance Selection among segregation generations:

Eighteen $F_2$ 's involving ICMS-81 B x Tall lines were raised in three row plots and extensive bagging prior to emergence of styles was done on the desirable segregants. The seed from selected single plants was harvested for further advancement and testing for non-restoration of fertility. Eight $F_3$ progenies advanced from $F_2$ were also studied and desirable plants were selected for further advancement and testing.
Forty five dwarf X tall $F_2$'s were raised and selection was made for fast growing vigorous, dwarf segregates with greater leafiness and quick regeneration. One $F_2$ progeny from a vigorous $F_2$ plant selected last year was observed promising. This progeny was further selected for obtaining stability of performance. Eighty six segregating lines were further advanced to derive new inbred lines through inbreeding.

Selection of parents for synthesis of new populations:

One hundred and thirty four inbred lines were advanced and selection was carried out for isolation of parental lines to be utilized for synthesis of new populations suitable for multicut system. The 16 lines selected for this purpose will be tested next year for stability of performance and their combining ability, both specific and general.

Multi-locational testing of promising varieties:

The population JFB-801 was further included in the final yield evaluation trials (FET) of the All-India Co-ordinated Research Project on Forage crops (AICRPFC). Also, based on their promising performance, three populations, viz., JFB-817, JFB-821 and JFB-822 were entered in the initial evaluation trial (IET) of the AICRPFC.

Induction of amphiploidy in Interspecific hybrid:

Amphiploidy was induced in the *Pennisetum americanum* × *P. purpureum* and *P. americanum* × *P. orientale* hybrids so as to develop plants with perennial nature and seed setting ability like normal bajra parent.

Collection of genetic material:

Two new male-sterile lines and some sweet stalk material was collected from ICRISAT for utilisation in the breeding programme.

2.5 Production and quality breeding in fodder barely (*Hordeum vulgare*)

(U. S. Mishra and Bhag Mal)

Germplasm evaluation:

The germplasm comprising 256 entries were grown in single 3m, long rows spaced at 50cm with plants 20 cm apart. Observations on days to flower, plant height, tiller num-
qer, leaf length, leaf width, leaf stem ratio, green fodder yield and dry matter percentage were recorded on five plants selected at random in each cultivar. A wide range of variation was observed in all the characters and the relative frequencies of cultivars falling into different grades of characters.

A wide range of genetic variation was observed for all the characters. The promising types with specific desirable traits were selected for further exploitation. The early flowering genotypes (56-61 days) were Icarda-210, K-670, Icarda-192, Icarda-113 and Icarda-131. The tallest variety was BP/RC-102 (121.3 cm) followed by BP/RC-56 (118.3 cm), BP/RC-17 (118.1 cm), BP/RC-54 (111.3 cm) and BP/RC-123 (111.3 cm). The tillers number showed a wide range (3.2-26.0). The profuse tillering genotypes were BP/RC-98 (26.0), BP/RC-41 (22.8) and BP/RB-34 (22.2).

The leaf number exhibited a range of 4.4-8.7, K-59 and Icarda-200 possessing more than 8 leaves per main tiller were considered promising. The promising genotypes identified for long leaves (more than 38 cm) were I. C. 36773, I. C. 36899, BP/RC-38, BP/RC-138 and BP/RC-112. The broad leaf types (2.34-2.46 cm) included K-633, Icarda-200, K-53, BP/RC-112 (0.90) followed by BP/RC-16 (0.74) and Icarda-206 (0.71).

The green fodder yield varied from 16.0 to 243.3 g per plant. The high fodder yielding genotypes were BP/RB-98, IC3 6959, Icarda-105 and BP/RB-18. The range of variation for dry matter percentage was 15.6 to 38.40 and IC-36934, IC-36903, BP/RC-16 Icarda-25 and BP/RB-93 were observed high dry matter yielding genotypes.

PI-3: BREEDING HIGH YIELDING VARIETIES OF CULTIVATED FODDER LEGUMES.

3.1 Breeding varieties for fodder yield and quality in cowpea (*Vigna unguiculata*).

(K. S. Kohli and C. B. Singh)

Varietal evaluation trial:

A replicated varietal evaluation trial with eighteen entries was laid out in randomised-block design at two sites at the C. R. farm. Data on dry matter yield revealed good performance of AY₇P₇ (150.06 q/ha) and VMPK-1 (104.04 q/ha) at site II. The entries producing substantial quantity of seed were I. L-978 (6.70 kg), I. L-984 (5.80 kg) and I. L-984 (5.80 kg).

(37)
Advancing of generations:

F₃ progenies driven from a cross 42-1 × 452 were evaluated for different characters. Twenty plants from promising progenies were selected on the basis of earliness, erect growth habit, synchrony in maturity and grain filling ability.

Thirty F₄ progenies of the inter-specific crosses Vigna unguiculata × V. cylindrica, V. cylindrica × V. sesquipedalis were raised. Eighty promising single plants were selected and the seed harvested separately to raise F₅ progenies. The sesquipedalis types dominated in the hybrids. Considerable variation was observed in the cross between V. Cylindrica × V. uniguiculata.

3.3 Genetic improvement of Trifolium Species with special reference to Egyptian clover.

(G. P. Shukla)

8 × 8 blend dial'el trial in Egyptian clover:

This experiment consisted of 8 parents and their 28 blends each with equal no. of seeds of both counterparts. Owng to prolonged water stress, it could not be possible to record observations for forage attributes. However, the data for seed yield was recorded on five randomly selected plants in each entry in each replication. The analysis of the data for seed yield potential indicated non-significant 'F' value. This could be due to involvement of uncontrolled error variance in a substantial proportion.

Selection and hybridization: Selection was performed in M₄ generation to constitute a new strain of Egyptian clover. Interspecific hybridization was carried out between T. alexandrinum × T. resupinatum, but no hybrid seed could be obtained.

Natural crossing between T. alexandrinum and T. resupinatum.

The progenies were raised from the seed obtained from previous years' experiment consisting of two rows of T. alexandrinum followed by a single row of T. resupinatum and studied for segregation pattern. The progenies showed no segregation for characters of either of the species. This indicated little chances for their interspecific hybridization in nature.

Seed multiplication: Five promising entries, viz., JHB 137, JHB 146, JHB 288 JHB 205 and JHB 220 were grown in isolation and the breeder seed was produced. JHB 137 was entered in All India Co-ordinated trials.
3.4 : Verietal Construction for Yield and Disease Resistance in Dolichose Complex (Lablab purpureus) (D. N. Singh)

Germp'asm evaluation :

Post flowering data on 73 lines sown in Kharif 1984 indicated that the lines were highly variable for all the characters except for plant length, no of nodes and length of vegetative period. Maximum C. V. was observed for No. of branches, no. of pods/plant and no. of fruiting inflorescence. The lines showed normal distribution for all the characters except for no. of branches and no. of fruiting inflorescence, for which skewed type distribution was observed. Outstanding lines possessing specific desirable characters were identified.

Yield trial on selected cultivars :

Yield data recorded in a trial involving 20 cultivars along with S-2214-II as a check showed that the cultivars were highly variable. For grain yield, S-32, S-18 and S-38 IV were found superior over check. Considering total productivity, S-18 and S-36 were the promising cultivars for dual purpose.

Mutagenic variability and its exploitation :

Seeds of the mutant plants (M1) of the varieties S-1649-I treated with 0.2% EMS for 6 and 12 hrs, variety S-2214-II for 6, 12, and 18 hrs and variety S-2214-II for 6, 12 and 18 hrs sown in July 1984 were harvested. In this generation some plants were very early. Seeds of mutants (M2) were sown in large size plots. Vegetative growth was normal. Observations were recorded on seedling vigour, tolerance to cold and water stress and preflowering attributes of the crop.

Irradiated populations in advance generation :

Seed of the individual plants (M1) originated from the irradiated material of S-2214-II treated with 25 kr, 80 kr and S-1649-I treated with 25 kr, 80 kr and 30 kr of gamma rays were harvested. M₃ progenies were sown in spaced planting in separate plots. Observations on seedling growth, vegetative period, plant types and tolerance to cold and water stress were recorded Selection between and within the families would be done at post flowering/maturity stage.
Intra-specific hybridization:

Out of a large number of crosses attempted between a number of selected strains belonging to var. *lignosus* and var. *typicus*, only four crosses involving S-1649-I as a recipient parent and S-22, S-23 and S-16 as donors were successful. A cross between S-22 × S-33 was also obtained. The donor parents, involved were highly diverse for the characters. Hybrid seeds were collected for their advancement.

F₁ plants of the cross IS-1649-IXS-16 showed earliness by 15–20 day. Similarly the cross between S-22 × S-23 showed hybrid vigour for vegetative growth. Other crosses were intermediate for most of the characters.

Advancing of hybrid generation: Morphological observations on pod and seed characters were recorded on plants of the F₃ progenies of nine crosses. The progeny of the plants originally selected for resistance in F₂ generation also showed incidence of cold and diseases. Progenies of the two hybrids i. e. S-1649-IX S-2214-II and S-1649-IX S-14 showing very poor performance were eliminated. For rest of the hybrids, 5 to 20 plants were selected and seeds were collected separately.

F₄ progenies of 7 crosses were raised and observations on growth, vigour, colour of the foliage and flower, plant types length of the vegetative period and tolerance to diseases were recorded.
Table: 6 Genetic Variability for Different Characters in *Lablab purpureus*.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Mean</th>
<th>C. V.</th>
<th>Range</th>
<th>Freq. distribution of cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V. low</td>
</tr>
<tr>
<td>Plant Length (cm)</td>
<td>71.9</td>
<td>18</td>
<td>40.7-102.2</td>
<td>7</td>
</tr>
<tr>
<td>Branches/plant</td>
<td>5.3</td>
<td>45</td>
<td>2.2-14.2</td>
<td>42</td>
</tr>
<tr>
<td>Nodes/plant</td>
<td>12.2</td>
<td>18</td>
<td>7.3-17.6</td>
<td>8</td>
</tr>
<tr>
<td>Pods/branch</td>
<td>8.2</td>
<td>37</td>
<td>2.3-20.6</td>
<td>15</td>
</tr>
<tr>
<td>Fruiting inflorescence</td>
<td>8.7</td>
<td>44</td>
<td>2.8-28.8</td>
<td>33</td>
</tr>
<tr>
<td>Pods/plant</td>
<td>43.5</td>
<td>49</td>
<td>9.4-107.1</td>
<td>20</td>
</tr>
<tr>
<td>Dry pod wt./plant (g)</td>
<td>35.6</td>
<td>40</td>
<td>9.0-68.7</td>
<td>10</td>
</tr>
<tr>
<td>Dry fodder wt./plant (g)</td>
<td>46.9</td>
<td>38</td>
<td>14.0-97.0</td>
<td>14</td>
</tr>
<tr>
<td>Early growth vigour (1-5 grade)</td>
<td>2.8</td>
<td>39</td>
<td>10.0-5.0</td>
<td>7</td>
</tr>
<tr>
<td>Vegetative period (A)</td>
<td>99.1</td>
<td>17</td>
<td>62.0-145.0</td>
<td>7</td>
</tr>
</tbody>
</table>
3.6 : Improvement of *Cajanus cajan* for high fodder and seed yield.

(C. B. Singh)

Evaluation of genetic diversity in pigeonpea was undertaken and detailed morphological observations for 18 plant characters were recorded at maturity on five randomly selected plants in each cultivar in each replication. Based on the data on total plant biomass (stem + leaf + green pods, dry matter basis), pod and seed yield, the following high productive lines were isolated: I. L.-677, 170, 26, 402, 158, 287, 324, 335–III, 345, 503, 569, 686, 580, 585, 544, 224, 365 and ICRISAT (GWALIOR) No. 9, 10 & 22.

The second trial comprised 55 lines of pigeonpea grown in pure and mixed stand with Jowar, Til and Mung bean. The morphological data on 18 plant characters at maturity indicated that mixed cropping with Jowar reduced the morphological expression of all the characters in all the lines of pigeonpea. The output of total plant biomass and green pods ranged from 160 to 863 g and 50 to 290 g in a pure stand, and 100 to 370 g and 20 to 170 g respectively in a mixed stand with Jowar. Similarly, the mean yield of all the cultures for total plant biomass and pod yield under cropping situation was 327 and 188 as compared to 151 and 65 g respectively for mixture with sorghum. The ratio of grain/pods to the total biomass and grain-pod yield was also comparatively less for pigeonpea lines grown in mixture than in a pure crop.

Only seven lines, viz IIL-677, IL-170, IL-26, ICRISAT, No. 22, ILO-402, IL-224 and IL-365 produced consistently high yield in both pure and mixed cropping situations.

PI-4 : BREEDING VARIETIES OF PASTURE SPECIES INCLUDING TREES AND SHRUBS FOR YIELD AND PERSISTENCE.

4.1 Varietal improvement for forage yield and quality in range grasses.

(Bhag Mal and U. S. Mishra)

*Cenchrus* species:

1. Seventy five entries of *Cenchrus ciliaris* grown in single rows were evaluated for different characters. Two cuts were taken during the year. A high degree of variation
was observed for fodder yield, plant height and tiller number in both the cuts. The pooled green fodder yield of two cuts varied from 933.3g to 1840.0g per plant, the highest being recorded for S–82–1. This was followed by S–82–3 (1283.3g), IGFRI 4190–1 (1251.7g) and S–82–1 (1110.0g). The tallest genotype was CAZRI–358 (193.3 cm) followed by S–82–3 (182.3 cm). The maximum tillers were recorded in IGFRI–4109–1 (88.3) followed by that in S–12 (79.0). Field observations revealed differential response of genotypes to shading. Eight genotypes, viz., S–2, S–8, S–23, IGFRI–626, IGFRI–627, IGFRI–632, IGFRI–3105 and IGFRI–3133 were observed to show good performance under the shade of subabool trees.

2. The germplasm comprising 44 entries of *Cenchrus setigerus* was evaluated and wide genetic variation was observed for plant height, tiller number and fodder yield based on the performance in two cuts ranged from 70.0 to 835.7g per plant, the highest being shown by IGFRI–4058–1 followed by IGFRI–2758–1 (747.0g). Two genotypes, viz., IGFRI–4058–1 and IGFRI–2758–1 showed consistent superiority during 1984 and 1985.

3. The entire germplasm of *Cenchrus ciliaris* and *Cenchrus setigerus* was maintained and seed multiplication of promising strains was done.

*Pennisetum pedicellatum* :

1. A replicated trial with 46 promising selections and mutant progenies was laid out to study the genetic variation in fodder yield potential and other plant characters. However, the material got damaged due to biotic disturbance and the trial had to be dropped.

2. Seed multiplication of promising selections as well as entries being tested in All India Co–ordinated trials, viz IGFRI–32–1, 43–1, 56–1, 865, 2734, 3808, 2–2–2, 4–1–2, 4–1–5 was done.

*Dichanthium* species :

1. The germplasm comprising 90 lines representing different *Dichanthium* species, *D. aristatum*, *D. serecium* and *D. supercellatum* as well as the natural hybrids between *Dichanthium* and *Bothriochloa* were evaluated. Two cuts were taken and the data on plant height, tiller number and green fodder yield were recorded. The pooled yield

(43, )
of two cuts varied from 333.0 to 1733.3g. The highest green fodder yield per plant was exhibited by IGFRI-575 which was followed by IGFRI-584 (1525.0g). Both these genotypes showed better performance than IGFRI-495-1.

2. The natural hybrid between Dichanthium and Bothrichloa showing better tussock formation and yield performance was multiplied for large scale yield testing. Seed multiplication of promising strains as well as the germplasm material was done for maintenance and further use.

4.2 Variety development for yield and resistance in range legumes:

(C. B. Singh and D. N. Singh)

1. Stylosanthes species:

The bulk seed progenies arising through auto-seedling in the same plot emerged at patches of thick population of young plants competing with native weeds. Though, the weeds appeared in abundance, the old biennial plants showed favourable competition against the weeds, but the young stylo seedlings coming up around the old plants apparently suffered very adversely on account of heavy competition/smothering effects of their own population density and due to faster growing weeds.

2. Macroptilium atropurpureum C. V. Siratro:

Seeds of auto-tetraploids produced semi-sterile plants in M₀ generation with thick and large size leaf and stem, but very poor seed setting. The seeds produced per plant were much bolder in size, but fewer in number.

PI-5 : PHYLOGENETIC STUDIES IN FORAGE AND PASTURE SPECIES.

5.2 Induction of genetic variability and selection of desirable plants types in some fodder crops through mutation.

(M. G. Gupta)

(44)
Seeds from various EMS and NMU treatments (0.025%, 0.05%, 0.075% and 0.1%) and the control from M₁ generation of S. sesban were collected from individual plants and pooled for respective treatments to raise M₂ generation.

Studies on seed germination and early seedling growth:

One hundred seeds of S. sesban per petridish per treatment with three replications for each treatment were sown and observations were taken seven days after sowing. The seed germination in highest dose of both EMS and NMU was adversely affected (control 77.5%, 0.075% EMS-57.0%, 0.075% NMU-69.0%, 0.1% EMS-49.5% and 1% NMU-60.0%). Higher concentrations of EMS and NMU had pronounced effect on shoot and root lengths (control 6.66 and 3.33 cm, 0.075% EMS-3.0 and 2.11 cm, 0.075% NMU-4.50 and 2.66 cm, 0.1% EMS-2.50 and 2.11 cm, and 0.1% NMU-2.33 and 3.0 cm) and dry matter weight (control-2.5 mg, 0.075% EMS-52.0 mg, 0.075% NMU-56.0 mg, 0.1% EMS-52.5 mg and 0.1% NMU-50.0 mg).

Studies on seed germination and early seedling growth were conducted in a separate experiment in polythene bags, filled with soil and manure mixture (2:1). Sowing was done at the rate of one seed per polythene bag. One hundred bags per treatment per replication were used. Observations on seed germination were taken after seven days of sowing and survival percentage, shoot/root lengths and dry matter weight of the seedlings were recorded after five days of sowing. The seed germination was adversely affected in higher doses of mutagen treatments (control-67.0%, 0.075% EMS-45.5%, 0.075% NMU-56.0%, 0.1% EMS-35.0% and 0.1% NMU-47.0%). Survival percentage of the seedlings was highly affected in higher doses of mutagen treatments (control-85%, 0.1% EMS-3.66% and 0.1% NMU-8.6%). Higher doses of mutagens showed remarkable effect on shoot and root lengths (control-15.0 and 29.0 cm, 0.075% EMS-12.5 and 24.0 cm, 0.1% EMS-11.5 and 19.0 cm and 0.1% NMU-12.0 and 17.0 cm) and dry matter weight (control-1590 mg, 0.1% EMS-1129 mg and 0.1% NMU-1254 mg) of the forty five days old seedlings.

Studies on plant attributes:

All the plant attributes were affected by higher concentrations of mutagen treatments in M₂ generation also (1) Plant height biomass—control-509 cm, and 0.1% NMU-412 cm, (2) Above ground biomass—control-5.4 kg; 0.1% EMS-4.3 kg; and 0.1% EMS-14.0 cm, and 0.1% NMU-14 cm (3) seeds per pod—control-25.0, 0.1% EMS-5.2, 0.1% NMU-9.0; and (4) pollen fertility—control 85%, 0.1% EMS-14% and 0.1% NMU-20%). Poor growth and high mortality, very less flowering, flower and bud dropping and very less seed setting occurred in higher doses of treatments of the mutagens.
Cytogenetical studies:

*Mitosis*: Effect of EMS and NMU were very pronounced in higher doses in M3 generation also causing the irregularities in the dividing root tip cells (control 1.6%, 0.1% EMS-27.7%, 0.1% NMU-22.9%). Laggards, non-disjunctions, bridges and fragments were the common aberrations observed in higher doses of mutagen treatments.

*Meiosis*: Pollen mother cells exhibited considerable disturbances both in metaphase-I (control-2.0%, 0.1% EMS-30.6% and 0.1% NMU-29.1%) and anaphase-I (Control-1.8%, 0.1% EMS 20.9% and 0.1% NMU-18.5%). Occurrence of multi and univalents, rings, chains and other abnormalities, such as clumping, laggards etc. were commonly observed in addition to the normal bivalents.

Effect of UV rays on *S. sesban*:

Fifteen days old seedlings were treated with the UV rays from 5-70 minutes. Flowering was delayed in 50 to 70 minutes treatments of UV, though the plants recovered from the inhibiting effects and gradually showed healthy appearance within four week time.

5.3 : Cytogenetical studies in forage legumes

(S. N. Tripathi)

Interspecific hybridization in *Atylosia* species

(i) Selected F5 plants of the cross *Atylosia albicans x Atylosia scarabaeoides*, were subjected to meiotic investigations alongwith the studies on pollen seed fertility and presented in Table-7. These F5 plants raised through S. S. D. were selected for their further advancement. There was a gradual trend of cytological stability (as reflected by high degree of chromosome pairing) and also pollen and seed fertility in these advanced plant progenies of interspecific hybrid. Further, the homology as evidenced by chromosome pairing between these species of *Atylosia* indicated phylogenetic relation.
Table 7: Chromosome association, pollen fertility and growth traits in F₅ plants of interspecific hybrid.

<table>
<thead>
<tr>
<th>Plant Nos.</th>
<th>Average chromosome associations at M₁.</th>
<th>Pollen fertility (%)</th>
<th>No. of primary branches</th>
<th>No. of secondary branches</th>
<th>Growth habit</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-1-9</td>
<td>11 II</td>
<td>92.0</td>
<td>28.0</td>
<td>61.0</td>
<td>Semi-erect coupled with high leafiness</td>
</tr>
<tr>
<td>13-3-21</td>
<td>10 II +2</td>
<td>80.0</td>
<td>19.0</td>
<td>63.0</td>
<td>Erect with branch ends dropping</td>
</tr>
<tr>
<td>14-1-17</td>
<td>11.0II +2</td>
<td>89.0</td>
<td>18.0</td>
<td>60.0</td>
<td>Spreading with profuse branching.</td>
</tr>
<tr>
<td>15-1-10</td>
<td>9II +4</td>
<td>87.5</td>
<td>26.0</td>
<td>71.0</td>
<td>Erect (bushy)</td>
</tr>
<tr>
<td>18-1-12</td>
<td>11 II</td>
<td>91.5</td>
<td>20.0</td>
<td>63.0</td>
<td>Semi-erect with main stem more woody.</td>
</tr>
<tr>
<td>18-1-3</td>
<td>9.0 II +4</td>
<td>69.0</td>
<td>17.0</td>
<td>70.0</td>
<td>Semi-erect, profusely branched and reduced internodal gaps.</td>
</tr>
<tr>
<td>25-1-1</td>
<td>11.0 II</td>
<td>86.5</td>
<td>15.9</td>
<td>65.0</td>
<td>Broad leaf</td>
</tr>
<tr>
<td>29-1-1</td>
<td>10. II +2I</td>
<td>75.0</td>
<td>14.0</td>
<td>78.9</td>
<td>Spreading</td>
</tr>
<tr>
<td>39-1-1</td>
<td>11 II</td>
<td>88.0</td>
<td>11.0</td>
<td>85.0</td>
<td>Winy</td>
</tr>
<tr>
<td>31-1-2</td>
<td>9 II +4</td>
<td>73.5</td>
<td>13.0</td>
<td>73.0</td>
<td>Prostrate with much slender branche.</td>
</tr>
</tbody>
</table>
ship amongst them. These plants possessing high leafiness, profuse branching, desirable growth habit and high degree of pollen and seed fertility could be useful for dryland situation.

(ii) Meiotic as well as palynological studies were made in trispecific hybrid *Atylosia albicans* × *Atylosia scarabaeoides* × *Atylosia cajanifolia*.

2. Improvement of *C. cajan* through gene transfer from wild species:

Cyto-morphological studies were made in some promising F₅ plants of the intergeneric cross *Atylosia cajanifolia* × *Cajanus cajan* (Table 8.)

Table 8: Chromosome association, pollen fertility and growth habit of F₅ plants of intergeneric cross.

<table>
<thead>
<tr>
<th>Plant Nos'</th>
<th>Plant Type</th>
<th>Average Chromosome association at M-1</th>
<th>Pollen fertility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>133-11</td>
<td>Erect, determinate</td>
<td>11 II</td>
<td>99.0</td>
</tr>
<tr>
<td>133-7</td>
<td>Bushy, dwarf, determinate and early type.</td>
<td>10 II+2 I</td>
<td>95.0</td>
</tr>
<tr>
<td>139-3</td>
<td>Vigorous spread, more basal branching, indeterminate and late maturing</td>
<td>11 II</td>
<td>97.0</td>
</tr>
<tr>
<td>92-6</td>
<td>Erect, profuse branching, late maturity with high leafiness</td>
<td>10 II+2 I</td>
<td>87.0</td>
</tr>
<tr>
<td>143-1-3</td>
<td>Bushy, dwarf, determinate and medium maturing.</td>
<td>11 II</td>
<td>94.0</td>
</tr>
<tr>
<td>135-4</td>
<td>Main stem more woody, erect round leaved, determinate and medium maturing.</td>
<td>10 II+2 I</td>
<td>89.5</td>
</tr>
<tr>
<td>5-1-2</td>
<td>Very high leafiness, high number of secondary and tertiary branches, high pod setting and early maturing.</td>
<td>11 II</td>
<td>98.5</td>
</tr>
</tbody>
</table>
The cytogenetic investigations have confirmed the close affinity between these two genera as evident by the production of normal fertile hybrids, and formation of 11 bivalents in some of these selected plant types. These fertile hybrids scored, were further isolated for advancing to next generation. Various plant types/ideotypes were identified which could find a place in dryland/rangeland areas.

Table 9: Chromosome associations and pollen stainability/size in parents and trispecific F₁ hybrid in the genus *Atylosia*.

<table>
<thead>
<tr>
<th>Plants</th>
<th>2n</th>
<th>Average chromosome associations</th>
<th>Pollen stainability (%)</th>
<th>(mean) size</th>
<th>Stainable pollen</th>
<th>Un-stainable pollen</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₁ of (A. albicans x A. scarabaeoides) (Female parent)</td>
<td>22</td>
<td>10 II+2</td>
<td>54.0</td>
<td>31.0</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Semierect-twiner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. cajanifolia (pollen parents)</td>
<td>22</td>
<td>11 II</td>
<td>98.4</td>
<td>40.0</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>Erect shrub</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trispecific F₁ hybrid</td>
<td>22</td>
<td>9 II+4 I</td>
<td>51.3</td>
<td>36.5</td>
<td>28.5</td>
<td></td>
</tr>
<tr>
<td>Erect with Branch ends drooping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parental materials having different morphological traits and growth habits in the genus *Atylosia* have shown close affinity in their chromosome compliments as evidenced by the formation of high degree of bivalents during meiotic cell division. The scope lies in developing new plant types which could be useful for increasing the pasture productivity.

5.4: Cytogenetical studies in range legumes

(S. N. Zadoo)

Induced tetraploids

(a) Studies on C₃ progeny of induced tetraploids of *Sesbania tetraprera*.

(49)
C₃ progeny of *S. teraptera* (2n=4x=24) was raised and analysed for meiotic behaviour. A detailed study of five individual plants revealed a high degree of multivalent associations. The average association per cell was $4.45 \, IV + 0.25 \, III + 2.05 \, II + 1.33 \, I$ (Table 10). The maximum possible association of 6 quadrivalents was realized in 20% cells, whereas a minimum association of 12 bivalents was not observed at all. The trend of decrease in quadrivalent frequency as observed from C₀ to C₂ was not maintained. The high frequency of multivalent associations coupled with abnormal chromosomal disjunction and possibility of other physiological disturbances by genome duplication as such caused a severe reduction in seed set and only a few shrivelled seeds could be harvested for further studies.

(b) Studies on C₀ plants of induced tetraploids of *Sesbania macrocarpa*.

Induced tetraploids were produced in diploid race of *S. macrocarpa* with a view of crossing it with natural tetraploid race of *S. macrocarpa*. Out of 25 seedlings treated with 0.25% aqueous solution of colchicine, only 5 plants were identified as tetraploids based on pollen size and stainability. While average pollen size registered an increase from 21.95 μ in diploids to 34.57 μ in tetraploids, pollen stainability showed a decrease from 99.36% in diploids to 87.53% in tetraploids. Cytological examination of a single plant revealed a high degree of multivalent association, the average association per cell being $4.25 \, IV + 0.71 \, III = 3.0 \, II = 0.71$ (Table 10). A maximum association of $6 \, IV + 2 \, II$ was observed in 30% cells. The lowest association of $2 \, IV + 8 \, II$ was observed in 5% cells whereas an association of 12 bivalents was not observed at all. Despite a high degree of pollen stainability, no seed could be harvested. Crossing the induced tetraploids with natural tetraploid race, both as male and female parents was not successful.

(c) Studies on C₂ progeny of *Sesbania aculeata*:

C₀ progeny of *S. aculeata* was raised and analysed for meiotic behaviour and fertility. Meiotic behaviour was typical of induced autotetraploids with high degree of multivalent associations. The average association per cell was $4.4 \, IV + 3.1 \, III + 0.1 \, II$ (Table 10) Univalent frequency was lower than the aforesaid tetraploids and trivalent configurations were not observed at all. The highest association of 6 quadrivalents was observed in 10% cells whereas the lowest association of $3 \, IV + 6 \, II$ was observed in 15% cells. Association of 12 bivalents was not observed in any cell. However, tetraploids of *S. aculeata* showed a reasonably good fertility, with about 40 to 50% seed set. The C₂ progeny however, needs to be studied for any possible break down and chromosomal stability.
Table 10: Chromosomal associations in induced tetraploids of *Sesbania*.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Quadrivalues</th>
<th>Trivalents</th>
<th>Bivalents</th>
<th>Univalents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td><em>S. tetragonata</em></td>
<td>2-6</td>
<td>4.45</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td><em>S. microcarpa</em></td>
<td>2-6</td>
<td>4.25</td>
<td>0.1</td>
<td>0.10</td>
</tr>
<tr>
<td><em>S. aculeata</em></td>
<td>3-6</td>
<td>4.40</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

(d) Studies on C₇ progeny of *Atylosia scarabaeoides*

C₇ progeny of colchicine induced tetraploids of *A. scarabaeoides* were raised and studied for pollen stainability. Like C₆ generation there was a plant to plant variation for pollen stainability percentage. Some individual plants which showed good pollen fertility and seed set at C₆ level and vigorous vegetative growth at C₇ level have been selected for further multiplication and evaluation. The cytological status of these plants is being worked out.

Studies on haploids in *Sesbania* species:

In view of earlier reports of poly-embryony in the genus *Sesbania*, an experiment was conducted to score the possibility of occurrence of twin seedlings in various species of *Sesbania*. Seeds of four *Sesbania* species were germinated in petri dishes. Out of these, only *S. aegyptica* showed the occurrence of twin seedlings with a frequency of 0.5 to 1.0%. Out of six twin seedlings isolated, two reached maturity. One of the two seedlings was comparable to diploid control. Cytological examination revealed it to be normal diploid with 2n=12 chromosomes and regular occurrence of 6 bivalents at meiotic metaphase. The sister plant had diminutive morphological features along with a tender unbranched stem. It exhibited a considerable reduction in all plant parts as compared to control (Table 11). The reduction in different morphological features varied from 11.67 to 67.85%. The Cytological analysis from PMC's revealed that the weak plant was a haploid with 6 univalents showing no pairing amongst themselves. Lack of chromosome pairing in haploid seedling, indicated
the absence of any intragenomal homology and confirmed $X=6$ as basic number of the genus *Sesbania*. These studies are being repeated in tetraploid races of *Sesbania*, where in the recovery of poly-haploids would throw considerable light on the origin of natural tetraploids.

Maintenance of induced translocation heterozygotes in *Sesbania aculeata*.

Various interchange lines of *S. aculeata* induced by $R$-rays, involving 4–12 chromosomes were sown and studied for occurrence of interchange configurations. Cytological studies of some randomly selected lines revealed that structural hybridity was maintained in the progeny indicating thereby that complementary gametes involving structural rearrangements were effective in fertilization. Chromosomal structural changes did not bring about any significant morphological change which could be used to identify such lines without resorting to cytological analysis. The only morphological marker was smaller pod size.

5.6 Cytogenetical studies in range grasses.

(M. G. Gupta)

Morphological studies:

Classification of existing germplasm of *Cenchrus ciliaris* was done on the basis of observations on plant height, branching pattern, leaf size, hairiness of the leaves, panicle size and shape of the spikelets and pollen size and three major categories were identified.

Cytogenetical studies:

Meiotic studies in dividing pollen mother cells were conducted in eleven lines of *C. ciliaris* and their chromosomal associations and ploidy levels were studied. IGFRI–8–4–2, 8–4–5, 619, 620, 621, 651, 652, 663 and 3802 showed $2n=36$ at diakinesis which showed autotetraploid nature of these accessions, IGFRI–494 ($2n=5x–1=44$) and 4109 ($2n=5x-3=42$) showed aneuploid nature.

Apomixis studies: Out of eight cultivars prepared for embryological studies, only three lines IGFRI–678, 8–2–4 and 358) could be studied successfully. All these three lines showed apomictic nature of embryo development.
Table 11: Morphological features of diploid and haploid *S. aegyptica*.

<table>
<thead>
<tr>
<th>Character</th>
<th>Diploid 2n=12</th>
<th>Haploid 2n=6</th>
<th>% reduction in haploid</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Stem</td>
<td>Stout branched</td>
<td>Slender unbranched</td>
<td></td>
</tr>
<tr>
<td>(b) Leaves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of leaflets/leaf</td>
<td>30-46 (37.5)</td>
<td>25-25 (23.3)</td>
<td>37.79</td>
</tr>
<tr>
<td>Leaf length (cm)</td>
<td>14.5-22.3 (18.1)</td>
<td>5.4-6.0 (5.82)</td>
<td>67.85</td>
</tr>
<tr>
<td>Leaf breadth (cm)</td>
<td>5.0-7.0 (6.0)</td>
<td>2.7-3.1 (2.94)</td>
<td>51.10</td>
</tr>
<tr>
<td>Length of largest leaflet (cm)</td>
<td>2.3-3.1 (3.0)</td>
<td>1.8-1.9 (1.84)</td>
<td>38.67</td>
</tr>
<tr>
<td>Breadth of largest leaflet (cm)</td>
<td>0.5-0.7 (0.56)</td>
<td>0.3-0.4 (0.36)</td>
<td>35.72</td>
</tr>
<tr>
<td>Length of smallest leaflet (cm)</td>
<td>0.3-0.6 (0.44)</td>
<td>(0.2)</td>
<td>54.55</td>
</tr>
<tr>
<td>(c) Flowers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of vexillum (cm)</td>
<td>1.8-2.2 (2.02)</td>
<td>1.0-1.1 (1.04)</td>
<td>48.52</td>
</tr>
<tr>
<td>Breadth of vexillum (cm)</td>
<td>2.0-2.4 (2.30)</td>
<td>1.5-1.6 (1.56)</td>
<td>32.18</td>
</tr>
<tr>
<td>Length of keel (cm)</td>
<td>1.4-1.6 (1.52)</td>
<td>0.8-0.9 (0.84)</td>
<td>44.74</td>
</tr>
<tr>
<td>Pollen grain size (µ)</td>
<td>24-30 (29.2)</td>
<td>9.0-30.0 (15.48)</td>
<td>49.7</td>
</tr>
</tbody>
</table>

Figures in parentheses indicate average.

(53)
6.1 Screening and Induction of drought tolerance in forage.

(R. B. R. Yadav)

The effectiveness of pre-sowing seed treatments with hardening (water), CCC, phosfon-D and B-nine for inducing drought tolerance in bajra (*Pennisetum americanum*) was studied. Seeds of bajra variety PSB-2 were sown in porcelain pots and study was confined to 43 days only. Pre-treatments reduced the transpiration loss with higher chlorophyll and ROC (relative water content) in plants whereas lower CSI (chlorophyll stability index) was recorded in hardening treatments in comparison to control (Table 12). However, among the growth retarding chemicals, B-nine was found to be more effective for inducing tolerance.

6.2 Screening and induction of salt tolerance in forages.

(O. P. S. Verma)

Two varieties of cowpea, viz, HFC-42-1 and Russian Giant were sown in pots under simulated conditions of four salinity levels (4, 8, 12 and 16 Ece). Sodium chloride, calcium chloride and magnesium sulphate were dissolved in ratio of 7 : 2 : 1 in water required to saturate 20 kg of soil in pots. In Russian Giant, plant height, number of leaves, fresh and dry weights of plants decreased with increasing levels of salinity. However, an increase in these characters was recorded in HFC 42-1 at moderate salinity level.

Seeds of berseem variety IGFRI-99-1 were sown in petri plates containing 2 ml salt solution of sodium chloride, sodium sulphate, magnesium chloride, magnesium sulphate and calcium chloride (0, 40, 80, 120 m.e% of each). Germination percentage was delayed in the higher concentrations of all the salts except calcium chloride. Root and coleptile growth were also influenced with increasing concentrations of salts, and effects on root growth were more pronounced under sodium salts.

6.3 Effect of growth regulators on flowering, seed setting and quality aspects of forages.

(R. B. R. Yadava)
Table 12: Drought tolerance of bajra plants under hardening treatments

<table>
<thead>
<tr>
<th>Days/Parameters</th>
<th>Control</th>
<th>water</th>
<th>50 ppm CCC</th>
<th>50 ppm phosphon-D</th>
<th>50 ppm B-nine</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 CSI</td>
<td>10</td>
<td>0.8</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>TC</td>
<td>0.85</td>
<td>0.97</td>
<td>1.12</td>
<td>1.15</td>
<td>1.20</td>
</tr>
<tr>
<td>RWC</td>
<td>65.0</td>
<td>70.2</td>
<td>74.7</td>
<td>72.8</td>
<td>76.4</td>
</tr>
<tr>
<td>DPD</td>
<td>10.5</td>
<td>11.7</td>
<td>12.6</td>
<td>12.1</td>
<td>13.2</td>
</tr>
<tr>
<td>T</td>
<td>15.8</td>
<td>12.7</td>
<td>10.2</td>
<td>9.3</td>
<td>7.1</td>
</tr>
<tr>
<td>29 CSI</td>
<td>14</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>TC</td>
<td>0.93</td>
<td>1.20</td>
<td>1.25</td>
<td>1.38</td>
<td>1.45</td>
</tr>
<tr>
<td>TWC</td>
<td>75.0</td>
<td>80.9</td>
<td>82.9</td>
<td>81.7</td>
<td>84.0</td>
</tr>
<tr>
<td>DPD</td>
<td>1.27</td>
<td>13.1</td>
<td>14.7</td>
<td>13.8</td>
<td>13.7</td>
</tr>
<tr>
<td>T</td>
<td>18.9</td>
<td>14.3</td>
<td>12.8</td>
<td>11.9</td>
<td>9.2</td>
</tr>
<tr>
<td>36 CSI</td>
<td>19</td>
<td>15</td>
<td>12</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>TC</td>
<td>1.15</td>
<td>1.36</td>
<td>1.35</td>
<td>1.45</td>
<td>1.59</td>
</tr>
<tr>
<td>RWC</td>
<td>82.5</td>
<td>84.7</td>
<td>87.8</td>
<td>65.4</td>
<td>89.9</td>
</tr>
<tr>
<td>DPD</td>
<td>12.9</td>
<td>14.0</td>
<td>14.9</td>
<td>14.8</td>
<td>14.5</td>
</tr>
<tr>
<td>T</td>
<td>20.6</td>
<td>15.1</td>
<td>13.8</td>
<td>12.6</td>
<td>10.8</td>
</tr>
<tr>
<td>43 CSI</td>
<td>17</td>
<td>13</td>
<td>11</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>TC</td>
<td>0.87</td>
<td>0.88</td>
<td>1.05</td>
<td>1.10</td>
<td>1.12</td>
</tr>
<tr>
<td>RWC</td>
<td>78.3</td>
<td>79.6</td>
<td>90.1</td>
<td>88.3</td>
<td>87.6</td>
</tr>
<tr>
<td>DPD</td>
<td>13.2</td>
<td>14.8</td>
<td>15.6</td>
<td>14.1</td>
<td>13.8</td>
</tr>
<tr>
<td>T</td>
<td>19.1</td>
<td>13.6</td>
<td>11.2</td>
<td>11.2</td>
<td>8.5</td>
</tr>
</tbody>
</table>

CSI: Chlorophyll stability Index  
TC: Total chlorophyll  
ROC: Relative water content.  
DPD=Diffusion Pressure Deficit  
T=Transpiration  

(55)
Healthy seeds of oat (*Avena sativa* L) cultivar—'Kent' were sown in field under heavily fertilised soil. Fifty days old plants were sprayed with various concentration of CCC and characters associated with lodging and seed yield were recorded at the time of harvest. Plants grown under high level of nitrogen fertilizer (120 kg/ha) showed retarded growth with increased doses of CCC. Breaking strength was considerably increased with decrease in stem length resulting higher resistance towards lodging. Likewise, seed yield and 1000 grain weight were also increased with foliar sprays of 1000 to 2500 ppm CCC (Table 13).

Table 13: Effect of CCC on lodging resistance and seed yield of oat.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Breaking strength</th>
<th>Lodging Index</th>
<th>Seed yield (q/ha)</th>
<th>100 grain wt. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>43.4</td>
<td>116.33</td>
<td>4.60</td>
<td>18.6</td>
<td>16.75</td>
</tr>
<tr>
<td>10 ppm</td>
<td>42.6</td>
<td>1283.33</td>
<td>4.25</td>
<td>17.2</td>
<td>17.33</td>
</tr>
<tr>
<td>100 ppm</td>
<td>40.8</td>
<td>1375.00</td>
<td>4.13</td>
<td>19.7</td>
<td>17.75</td>
</tr>
<tr>
<td>1000 ppm</td>
<td>40.2</td>
<td>1463.33</td>
<td>3.18</td>
<td>23.1</td>
<td>18.66</td>
</tr>
<tr>
<td>2500 ppm</td>
<td>37.5</td>
<td>1576.66</td>
<td>2.82</td>
<td>19.2</td>
<td>17.08</td>
</tr>
<tr>
<td>5000 ppm</td>
<td>37.0</td>
<td>1735.33</td>
<td>2.44</td>
<td>17.0</td>
<td>16.28</td>
</tr>
<tr>
<td>C. D. at 5%</td>
<td>2.96</td>
<td>220.65</td>
<td>NS</td>
<td>2.42</td>
<td>0.63</td>
</tr>
<tr>
<td>C. D. at 1%</td>
<td>3.92</td>
<td>313.90</td>
<td>NS</td>
<td>3.42</td>
<td>0.87</td>
</tr>
</tbody>
</table>

(56)
7.2 Analysis of resistance in selected fodder crops against important plant diseases.

(S. T. Ahmad)

Heavy infection of leaf spot on lucerne and berseem was noted this year as compared to previous year. Rest infection was mild on lucerne, bajra and Sesbania. Downy mildew was present on Medicago denticulata, M. sativa and other Medicago and Melilotus species. Helminthosporium leaf spot infection was heavy on sorghum and less on oats. Guar and sarson were found infected with Alternaria leaf infection. Many grasses were observed to harbour leaf spots besides known rusts.

An experiment was conducted to evaluate the efficacy of Derosal on the disease control and production of Jowar. Cultivars HD-1, HD-2, 4816, 1328 and pioneer were sown in 2 x 3 m plots replicated 4 times. Fungicide spray with 1.5%, 0.5% and 0.25% concentration was done. Data on fodder weight of the selected plots from each replication revealed differences. Rough leaf spot on sprayed plants was low in intensity as compared to unsprayed plants. Cowpea and guar plants were raised in pots and were sprayed with Bavistin and Derosal. The Bavistin sprayed plants showed better growth with trace of powdery mildew infection of guar. Other leaf spots of guar and cowpea did not appear on sprayed and unsprayed plants. However, these two fungicides appeared to be helpful for controlling leaf spot diseases.

Bajra cultivars, which showed rust/smut resistance during Kharif 1984 did not show any rust infection during 1985. However, all cultures showed varying degree of smut infection. Again few plants were selected and harvested separately for further studies. Forty one oat cultivars belonging to diploid, tetraploid and hexaploid species along with thirty hybrid progenies in F3 and F4 generations were sown and established plants were inoculated with stem and crown rust of oats. The rust infection on these plants did not differ from the original reaction of these cultivars. So far no culture could be observed as having adult field resistance. Avena nuda and A. sterilis developed crown rust infection. A. abysinica and A. longiglumis were highly susceptible.

( 57 )
7.3 Problem and prospects of plant diseases in graminaceous fodder crops.

(Arun Kumar)

Germplasm screening:

(a) Forage sorghum:

Eight cultivars of forage sorghum were observed under field conditions for the occurrence of different diseases. The severity was measured taking third leaf from the top into consideration after eighty five days of sowing. Two foliar diseases, viz., anthracnose and Exserohilum blight were observed on 6 cultivars obtained from ‘Hiss r’. The severity of anthracnose varied from 52.5% in S-263 to 58.5% in JS-20. The severity of blight ranged between 22.1% in S-260 and 28.5% in S-307. Two entries obtained from ICRISAT, Hyderabad were found affected by zonate leaf spots, blight, anthracnose and grey leaf spot. IS-18758 was completely free of anthracnose symptoms, but showed blight in traces to 5% severity.

(b) Bajra:

Out of 7 fodder bajra cultivars, entry P-310-7 exhibited 25% of leaf blast severity in sixty days old plants on second leaf from the top. Rest of the entries were free from blast smut, ergot and rust symptoms.

(c) Bajra × P. oriental hybrid and their back-crosses:

Bajra × P. oriental hybrids and their back-crosses (BC-1 and BC-2) were screened under field conditions against ergot and rust diseases. In F₁ hybrid, ergot incidence of 38% with 15.5% severity was recorded. Pennisetum orientale was observed free of ergot symptoms. The ergot incidence was 74% with 29.5% severity in BC-1, while the same was 48.3% with 18.3% severity in BC-2. P. orientale was observed free of rust symptoms. BC-1 plants were observed with 60% incidence and 12.5% severity. The average incidence of rust in BC-2 was 77% with 27% severity. The fourth leaf from below was screened for rust.

An experiment on ergot control was undertaken with an antitranspirant (8-Hydroxyquinoline). Seeds of variety BJ-104 were sown in the field and the chemical in 100,200 and
300 ppm concentration was sprayed at boot stage. Due to non-availability of fresh honey-dew, no artificial inoculations were made and the treated and control plants were left as such in the field. After twenty days of treatment, the plants were assessed for the disease. Control plants were observed with 62.0% incidence and 25.8% severity, but all the treated plants were freed of the disease symptoms.

### 7.4 Plant disease problems in browsing shrubs and trees.

(H. K. Joshi)

Six leaves on Albizia lebbek were tagged and ten leaflets on each leaf were observed to record the increase in number of rust pustules and the size of pastules on six different dates. The different weather variables, viz., maximum temperature (MXT), minimum temperature (MNT), mean temperature (MT), mean relative humidity (MRH), rainfall and the number of rainy days (Table 14) were analysed for their influence on the development of disease in terms of average number and size of spots during these days.

The data (Table 15) indicated that maximum size and number of rust pustules were recorded on 13.9.85 when the rainfall was less along with less number of rainy days.

**Table 14: Environmental factors prevalent during preceding week of observation (Average of seven days).**

<table>
<thead>
<tr>
<th>Observation data</th>
<th>MXT (°C)</th>
<th>MNT (°C)</th>
<th>MT (°C)</th>
<th>MRH I</th>
<th>MRH II</th>
<th>MRH Av.</th>
<th>Rainfall (mm)</th>
<th>No. of rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-8-85</td>
<td>31.3</td>
<td>22.3</td>
<td>26.8</td>
<td>85.0</td>
<td>57.0</td>
<td>71.6</td>
<td>180.5</td>
<td>7</td>
</tr>
<tr>
<td>8-8-85</td>
<td>32.7</td>
<td>23.9</td>
<td>28.3</td>
<td>76.5</td>
<td>39.1</td>
<td>57.8</td>
<td>105.4</td>
<td>4</td>
</tr>
<tr>
<td>14-3-85</td>
<td>32.7</td>
<td>25.4</td>
<td>29.0</td>
<td>80.8</td>
<td>48.4</td>
<td>64.6</td>
<td>81.0</td>
<td>3</td>
</tr>
<tr>
<td>23-8-85</td>
<td>31.9</td>
<td>23.7</td>
<td>27.8</td>
<td>86.5</td>
<td>61.0</td>
<td>73.7</td>
<td>135.0</td>
<td>6</td>
</tr>
<tr>
<td>5-9-85</td>
<td>31.2</td>
<td>25.7</td>
<td>28.4</td>
<td>79.2</td>
<td>50.2</td>
<td>64.7</td>
<td>50.4</td>
<td>2</td>
</tr>
<tr>
<td>13-9-85</td>
<td>32.4</td>
<td>24.3</td>
<td>28.3</td>
<td>86.3</td>
<td>63.5</td>
<td>74.9</td>
<td>41.6</td>
<td>1</td>
</tr>
</tbody>
</table>

(59)
Table 15: Increase in size and number of rust pustules on *Albizia lebbek*

(Average of 60 leaflets)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Date of observations</th>
<th>Size (mm)</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-8-85</td>
<td>8-8-85</td>
<td>14-8-85</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STUDIES ON INSECT-PESTS OF FORAGE CROPS, THEIR IMPORTANCE AND CONTROL.

8.1 Genetic evaluation of important non-leguminous crops for resistance to insect-pests

(S. A. Faruqui and K. C. Pandey)

1. Evaluation of sorghum germplasm for reaction to shootfly:

Sorghum germplasm comprising 106 lines was evaluated for reaction to shootfly, *Atherigona soccata*, based on no. of eggs, no. of dead hearts and injury to plant. IS-No's 3113, 3114, 3234, 3243, 3265, 3274, 3283, 3295, 3315, 3328, 3337 showed moderate resistance to this fly.

2. Evaluation of sorghum germplasm for reaction to midge:

One hundred and six lines of sorghum were screened for resistance to sorghum midge, *Conterinia sorghicola*. The early flowering lines, in general escaped midge damage, while late flowering lines showed increased damage. Based on midge damage the lines were categorized into following classes.

(60)
Resistant: IS No's—703, 704, 969, 1071, 3199, 3230, 3237, 3246, 3247, 3258, 3252, 3265, 3283, 3212, 3314, and 3341.


8.2: Genetic evaluation of important forage legumes for resistance to insect pests.

(K. C. Pandey and S. A. Faruqui)

1. Spotted alfalfa aphid, (Therioaphis maculata) on resistant and susceptible Medicago spp.

Eight cultivars of four *Medicago* species with one resistant and one susceptible cultivar of each species were studied. The adult survival on resistant cultivars was similar to that of starved aphids. Total production of aphids was 3–4 times more on susceptible cultivars, indicating that 'resistant' cultivars contain something that inhibit the production of nymphs in *M. sativa* (caliverda), *M. intertexta* (SA 2132), *M. litorallis* (SA 3072) and *M. truncatula* (SA 1450). Among the plant parts, leaves were more resistant. Non-preference for resistant plants, indicated the possibility of presence of a repellant in the phloem or inability to satisfy dietary requirements of the aphid.

2. Feeding response of alfalfa weevil to various sugars and related compounds.

The leaf disk bioassay was used to test the activity. The compounds were glucose, fructose, galactose, maltose, xylose, soluble starch, ascorbic acid. Comparisons were made at 0.25% and 1.25% (wt/v in water). Sucrose was superior to all other compounds as a weevil feeding stimulant. Ascorbic acid failed to exhibit feeding stimulant activity.
3. The seeds of 150 lucerne plants moderately resistant to lucerne weevil, *Hypera postica* were tested for mass selection against this insect. Out of 6000 seedlings, 600 were found resistant in adult cotyledon test. These were put under adult leaf disk test and about 400 plants were selected based on least damage and were put for larval development test. Out of these, 200 plants were put for oviposition stimulus test and finally about 100 resistant plants were selected and their seed collected.

4. Reaction of *arhar* and cowpea germplasm to pulse beetle *Collosobruchus maculatus*.

   Based on number of eggs, loss in seed weight and number of adults produced, 11–291, 73, 1517, 267 and 250 of *arhar* were found moderately resistant. In cowpea, varieties Kanyakumari, UPC–9020, VMPKV–1, JC–21 showed tolerance against this insect.

PI–9 : STUDIES ON NEMATODES IN RELATION TO FORAGE AND PASTURE PRODUCTION.


   (N. Hasan)

   (A) Fungus–Nematode interactions :

   The interaction involving *Fusarium oxysporum* and *M. incognita* on the week old *S. grandiflora* seedings were investigated with artificial inoculations with 2g of the fungal mat and 2000 freshly hatched larvae of *M. incognita* plant. *S. grandiflora* seeds were sown in 15 cm clay pots containing autoclaved soil and 7 days after germination the following treatments were given (1) control (2) fungus alone, (3) nematode alone (4) nematode–fungus. After 60 days of treatment data on growth and disease index were counted. The data revealed that combined effect of fungus and nematode caused greater severity of the disease than with either pathogen alone.

   (B) Pathogenicity of spiral and stunt nematodes and varietal screening in guniea grass :

   Pathogenicity tests of the above two species of nematodes on guniea grass (*Panicum maximum*) were conducted. Seeds of 25 strains were sown in 15 cm, earthen pots containing
nematode free soil. One week after emergence, single seedling was retained and inoculated with 0, 10, 1000, 2500 and 10,000 nematodes. Each treatment was replicated 3 times. Observations on various growth parameters and final population were recorded 90 days after inoculation.

Both stunt and spiral nematodes independently are pathogenic to guinea grass and can cause significant growth reduction at an initial inoculum level of 10,000 nematodes/pot. None of the lines tested were found to be resistant against these two nematode species. However, difference in the degree of susceptibility was observed, as indicated by the rate of reproduction of the nematode.

(C) Pathogenicity of root knot and reniform nematodes and varietal screening of field bean (*L. purpureus*).

The results of pathogenicity tests indicated that the growth of the plants was negatively correlated with the level of inoculation of both the nematodes. None of the 14 lines tested were found to be resistant to these nematode species.

(D) Screening of different *Medicago* species against root-knot nematode.

Wide variability in the degree of susceptibility to the root-knot nematode was observed, in which *M. littoralis* was found to be resistant.

9.3 : Studies on nematodes associated with silvopastoral systems.

(M. I. Azmi)

1. Anjan grass (*Cenchrus ciliaris*) :

   Stunt nematode : Fields as well as green house nurseries of anjan grass were found to be harbouring large population of *T. vulgaris*. In an experiment conducted with a view to investigate pathogenicity of *T. vulgaris* on anjan grass, data on the growth response and rate of nematode multiplication in each of the inoculum levels (0, 10, 100, 1000 and 10,000) indicated that the reduction in growth characters was most significant at higher inoculum levels (1,000 & 10,000).

2. Subabool (*Leucaena leucocephala*)

   Root-knot nematode—During survey, *Meloidogyne incognita* was found to be the dominant species of root-knot nematode attacking and forming galls in the roots of subabool Inoculum studies on the effect of *M. incognita* on growth of subabool seedlings at 0, 10, 100
500, 1000, 5000 and 10,000 inoculum levels indicated that the length as well as fresh and dry weights of shoot decreased as the inoculum density of the larvae increased. Reduction in growth occurred with 590 larvae per 500 ml. Plants were stunted, yellowing, browning and defoliating. Severe galling on the roots was observed. In 100 days, 100 *M. incognita* increased by 20,000 and 10,000 larva to 30,000.

Lesion nematodes: Effect of *Paratylenchus zaeae* on the growth of *subabool* seedlings and its control through phorate was studied. The length and dry weight of shoot and root of *subabool* decreased as the inoculum density increased. Reduction in growth occurred with 100 nematodes per 500 ml of soil and plants were stunted, yellowing and defoliating. In 100 days, 100 nematodes in 500 ml of soil increased to 27,000 and 100 nematodes in 1500 ml soil increased to 33,000. The length and dry weight of shoot and root of *subabool* increased where phorate was added at 0.05 and 0.5 g ai/l of soil mixture. The nematode population declined in inverse proportion to the amount of phorate applied. It is concluded that *P. zaeae* is pathagenic to *subabool* and is controlled by phorate applied to soil. Phorate applied to seed was also effective in controlling *P. zaeae*, but was phytotoxic especially at the higher rate.


Root knot nematode: Five species of *stylosanthes*, viz., *S. scabra*, *S. hamata*, *S. viscosa*, *S. humilis* and *S. guanensis* were tested under greenhouse condition for their reaction against root knot nematode, *Meloidogne incognita*. Nematodes on *S. scabra*, *S. humilis* and *S. viscosa* were smaller (1 to 1.5mm) than on *S. hamata* and *S. guanensis* (2.3 to 2.5mm). Significant reduction in *Rizobium* nodulation was observed in all species the highest being *S. guanensis* (19%) followed by *S. viscosa* (50%). Maximum reduction in plant growth was observed in *S. guanensis* followed by *S. humilis*.

Stunt nematode: A field experiment was carried out in natural sandy loam soil to evaluate the efficacy of low doses (0.5 and 1.0 kg ai/ha) of four systemic nematicides, viz., phenamiphos, aldicarb carbofuran and phorate for the control of stunt nematode *T. vulgaris* on *S. hamata*. The significant highest increase (39%) in the total herbage production (5 cuts), was observed in the fields treated with aldicarb @ 1.0 kg ai/ha followed by (36%) phorate and Carbofuran @ 1.0 kg ai/ha and 32% in case of phenamiphos @ 0.5 kg ai/ha. Higher doses of phenamiphos @ 1.0 kg ai/ha produced chlorosis. Maximum reduction in the nematode population was observed in the plots treated with phenamiphos followed by aldicarb.
3.1 Evaluation of varietal response of forage crops.

(S. N. Tripathi)

1. Comparative performance of cereal forage at different levels of nitrogen during kharif season.

(S. N. Tripathi & A. S. Gill)

This was first year of the experiment in which maize (African tall) fodder sorghum (Pioneer hybrid-988), pearl millet (giant bajra), *Pennisetum Pedicellatum* (IGFRI-43-1) were evaluated at three levels of nitrogen (30, 60 and 90 kg/ha) in randomised block design with three replicates. The soil of the experimental plot was sandy loam intermixed with murrum and shallow in depth. Nitrogen was applied in two splits, 2/3rd at sowing and 1/3rd at 40 days of growth. Phosphate @ of 30 kg P$_2$O$_5$/ha was given to all the treatments as a common dose at sowing. The crops in general were affected due to continuous rains for most part of the growth period.

The results showed that *Pennisetum Pedicellatum* recorded maximum yield (260 q/ha green and 52.7 q dry matter/ha) but was statistically at par with fodder sorghum 244 q green and 49.5 q dry matter/ha. The forage yield of maize (192.0 q green and 41.1 q/dry matter and bajra 175 q green and 38.9 q dry matter/ha) were statistically similar and significantly lower than sorghum and *Pennisetum Pedicellatum*. Application of increasing doses of nitrogen increased forage yields with the result that the maximum yield was obtained with 90 kg N/ha (250 q green and 52.1 q dry matter/ha). This was significantly higher to the yields obtained at 60 and 30 kg N/ha. The interaction between crops and levels or nitrogen was non significant.
2. Evaluation of *Pennisetum Pedicellatum* varieties at different levels of nitrogen.

(S. N. Tripathi and A. S. Gill)

Three varieties of *Pennisetum Pedicellatum* (IGFRI-43-1, 866-1 and 32-1) were compared at four levels of nitrogen (30, 60, 90 and 120 kg/ha) in randomised block design with three replicates on a shallow rakar soil. Phosphate @ 30 kg P$_2$O$_5$/ha was given to all the treatments at the time of sowing. Nitrogen was applied as per treatments in two splits—2/3rd basal and 1/3rd after 60 days of growth.

Results showed that variety IGFRI-43-1 recorded highest forage yield (291 of green 65.5 q dry matter/ha) followed by IGFRI-32-1. However, the differences in green and dry forage yield among the varieties were statistically non-significant. Nitrogen fertilization increased the forage yield and the highest production of 337 q/ha of green forage was recorded at 120 kg N/ha. The differences in green forage yields between 60 & 90 and 90 & 120 kg N/ha were however, not significant. Dry matter yield increased significantly upto 90 kg N/ha with a yield level of 75.0 q/ha.

3.2 Cultural management and fertilizer use in forage/pasture crops.

(A. S. Gill & S. N. Tripathi)

1. Effect of seed rates and levels of phosphate on forage yield of pea (variety T-163).

This was third year of the trial. The treatments consisted of all combinations of three seed rates (80, 100 and 120 kg/ha) and four levels of phosphate (0, 30, 60 and 90 kg P$_2$O$_5$/ha) in randomised block design replicated three times. The soil of the experimental plot was rakar in nature. Nitrogen @ 20 kg/ha was given to all the plots at the time of sowing. Phosphate was applied as basal through single super phosphate as per treatment. The crop was harvested for forage at pod formation stage after 192 days growth.

Results showed that increasing seed rates increased forage yields but the difference between 100 (318.0 q GM and 69.8 q DM/ha) and 120 kg/ha (336 q GM and 74.7 q DM/ha) seed rates were not significant. Similarly, addition of phosphate upto 90 kg/ha recorded
increased production of forage but the yield differences between 60 (369 q GM and 79.3 q DM/ha) and 90 kg P₂O₅/ha (380 q GM and 83.6 q DM/ha) were not significant. The additional forage obtained at 60 kg P₂O₅/ha was 21% and 76% higher over 30 kg P₂O₅/ha and control (no phosphate) respectively.

2. Effect of seed rates on forage yield of turnip.

Even seed rates of turnip (purple top) were compared for forage yield in randomised block design with three replicates. The crop received a basal fertilizer dose of 30 kg N+45 kg P₂O₅/ha. Top dressing with 30 kg N/ha was done after 35 days of crop growth.

Results indicated that use of 5 kg seed/ha recorded maximum forage yields (472 q GM and 42.2 q DM/ha) consisting of 225 q leaves (18.3 q DM) and 247 q roots (23.9 DM). Sowing of 2 kg seed/ha produced lowest forage yield (258 q GM and 23.1 q DM/ha).

3. Effect of seed rates, row orientation and fertilizer levels on mixed crop of forage sorghum.

The treatments comprised pure crops of sorghum, (Pioneer-988) and cowpea (HFC-42-1) and their mixed cropping treatments involving all possible combinations of three seeding rates (50%, 75% and 100% seed rates of sorghum and cowpea); two row arrangements (alternate and alternate paired rows) and two fertilizer levels (55 kg N+45 kg P₂O₅/ha and 90 kg N+30 kg P₂O₅/ha). The experiment was laid out in randomised block design with three replications. The crop was sown in 25 cm apart rows using seed rates of 40 and 50 kg/ha for pure crops of sorghum and cowpea respectively. In mixed crops the seeding rates were adjusted according to the treatments. Sorghum and cowpea were fertilized with 90 kg N+30 kg P₂O₅ and 20 kg N+60 kg P₂O₅/ha in sole cropping. Except in pure crop of cowpea, nitrogen was applied in two equal splits, at sowing and 40 days of crop growth. The crop was harvested for forage after 74 days of growth.

Results showed that forage yields of pure crop of sorghum and cowpea were 358 q/ha (78.9 q DM) and 222 q/ha (41.9 q DM) respectively. Mean forage yield of mixed crop treatments was 391.0 q/ha (81.3 q DM). Sowing of sorghum and cowpea in alternate paired rows gave significantly higher yields (414 q GM and 86.4 q DM/ha) over sowing in single alternate rows (368 q GM and 76.2 q DM/ha). Using 75% of the normal seed rate of cereal and legume components for mixed cropping recorded significantly higher green and
dry matter production over 50% of the normal seed rate. Increasing the seed rate to 100% did not give additional advantage. The effect of fertilizer levels on crop mixtures was not significant although fertilizing with 90 kg N+30 kg P₂O₅/ha recorded higher forage yields (401 q GM and 83.4 q DM/ha) over that of 55 kg N+45 kg P₂O₅/ha (381 q GM and 79.2 q DM/ha). The interaction of sowing method × seed rate was significant and mixed cropping in alternate paired rows using 75% seed rate of the component crops recorded significantly higher forage yields (471 q GM and 98.3 q DM/ha) over other combinations.

4. Studies on pure and mixed cropping of three fodder sorghum varieties.

This was the first year of the experiment and the treatments consisted of pure and mixed sowing of three multicut sorghum varieties (SSG-59-1, M. P. Chari and Pioneer hybrid-988) in a randomised block design with four replicates. The crop was sown on 20th April 1985 with an uniform row spacing of 25 cm and basal fertilizer dose of 60 kg N+30 kg P₂O₅/ha. Three cuttings for forage were obtained upto 24th October 1985. Nitrogen @ 60 kg/ha was given to the crop after first and second cuttings.

Results indicated that pure crop of Pioneer hybrid-988 recorded maximum green forage yield (814.5 q GM/ha) which was significantly higher to all other pure crops and their combinations except SSG-59-1 (756.8 q/ha). Pioneer hybrid also gave highest dry matter yield (184 q/ha) but SSG 59-1 (168.5 q/ha) and mixture of M. P. Chari and Pioneer (171.7 q/ha) produced statistically similar dry matter yields.

5. Studies on Rabi maize.

This was first year of the trial. The treatments consisting of the combinations of two row spacings (25 and 40 cm) and two seed rates (40 and 80 kg/ha) were replicated five times in randomised block design. Maize variety Pratap selection was sown as per treatment on 15-12-84 with a basal fertilizer dose of 60 kg N+60 kg P₂O₅+60 kg K₂O/ha. The crop was top dressed with 30 kg N/ha, 35 days after sowing. The crop was harvested for forage after 91 days of sowing.

Results indicated that use of 80 kg seed/ha recorded significantly higher green and dry matter yields (483 q GM and 115.4 q DM/ha) over 40 kg seed/ha (417.5 q GM and 99.7 q DM/ha). The yield differences due to spacings were not significant.
6. Effect of levels of nitrogen and seed rates on the forage yield of sorghum (Hybrid 988).

The trial was repeated in the second year to find out the optimum nitrogen and seed rate of fodder sorghum during kharif season. The treatments consisted the combinations of 3 levels of nitrogen (30, 60, and 90 kg/ha) and 3 seed rates (30, 40 and 50 kg/ha) in randomised block design with three replications. The crop was sown on June 20 in rows 25 cm apart and half the nitrogen was applied at sowing and the remaining half was top dressed just after first cut. Two cuts were taken on August 16 and October 24, respectively.

There was a linear response to the application of nitrogen on green and dry matter yields. Similarly with the increase in seed rate from 30 to 50 kg/ha the green and dry matter yield increased significantly. Highest green fodder yield (454 q/ha) was obtained with 90 kg N and 50 kg seed/ha. This confirms the results obtained in first year.

3.4 Evaluation and standardization of practices for dryland forage including range and pastures.

1. Effect of seed rate and method of sowing on the forage yield of senji under partially irrigated conditions.

(A. S. Gill and B. D. Patil)

This was the first year of the trial. The objective was to standardise the methodology of sowing senji (S-76) and working out the optimum seed rate. Treatments comprised two seed rates (20 and 30 kg/ha) and four methods of sowing (broadcast, line sowing at 25 cm apart, crops sowing at 25 cm spacing from both the sides, and sowing on 25 cm apart ridges. In all 8 treatments, combinations were evaluated in randomised block design with three replications. The trial was sown on October 31 with a basal dose of 30 kg N and 50 kg P2O5/ha. The crop was harvested for green fodder yield on Feb. 13.

A seed rate of 30 kg/ha gave significantly higher green fodder (303 q/ha) and dry matter (86.0 q/ha) yields over 20 kg/ha. Method of sowing was found to be non-significant. Interaction between seed rate and method of sowing was also non-significant.

2. Studies on Medicago scutellata (Snail medic)

(A. S. Gill and B. D. Patil)
This was the second year of the experimentation. The objective of the trial was to work out the phosphate requirement of Medicago scutellata, a rabi leguminous fodder crops. Treatments consisted of five levels of Phosphorus (0, 15, 30, 45 and 60 kg P₂O₅/ha) in randomised block design with four replicates. The crop was sown on November 18 in rows 40 cm apart with seed rate of 15 kg/ha and basal does of 20 kg N/ha. The crop was harvested for forage on February 7.

The results indicated that phosphorus fertilization significantly increased the green and dry matter yields of snail medic upto 45 kg P₂O₅/ha (205 q GM and 52.7 q DM/ha) and the increase was in the order of 118% and 120% over control (no phosphorus) respectively.

3. Cutting management studies in fodder sorghum (Hybrid-988).

(A. S. Gill)

This was the second year of the investigation. Treatment combinations comprised 4 stages of cutting (Boot, 50% flowering, Milk and dough) and two stubble height (close to the ground and 15 cm above the ground) in randomised block design with replicates. The crop was sown on July 10 in rows 25 cm apart using 40 kg seed rate/ha, basal fertilizer schedule consisted of 60 kg N and 30 kg P₂O₅/ha. The crop was harvested for green fodder as per the cutting treatments.

The crop registered maximum green (337 q/ha) and dry matter (81.8 q/ha) yields at milk stage. Both green fodder and dry matter production showed declining trend beyond this stage. Cutting the crop close to the ground was a profitable propositions as compared to cutting the crop 15 cm above the ground level.

4. Mixed cropping studies in Stylo and cereal fodder crop.

(A. S. Gill)

The experiment was initiated during the period under report to find out the best cereal (bajra giant) and legume (Stylo) combination for higher biomass production. Treatments comprised pure Stylo (6 kg/ha), pure bajra (10 kg/ha), Stylo (6 kg/ha)+bajra (10 kg/ha), Stylo (3 kg/ha)+bajra (5 kg/ha), Stylo (2 kg/ha)+bajra (6.66 kg/ha) and Stylo (4 kg/ha) +bajra (3.33 kg/ha) in randomised block design with 4 replications. The experimental
crop was sown on July 11 with a basal fertilizer dose of 30 kg N/ha and 30 kg P₂O₅/ha. Top dressing of 30 kg N/ha was done on August 12 only to the cereal component. The crops were sown in rows 30 cm apart (for mixed cropping treatments Stylo and bajra were sown mixed in the same rows).

Maximum green (296 q/ha) and dry matter (63.8 q/ha) yields were registered with cropping of stylo (6 kg/ha) and bajra (10 kg/ha). The highest yield of legume component was registered in pure sowing of stylo at 6 kg/ha. Taking into consideration the mixed cropping treatments, the maximum stylo yield (34 q/ha GM and 6.8 q/ha DM) was obtained when legume and cereal were sown at the second rates of 3 and 5 kg/ha respectively.

Interestingly the highest yield from cereal was (276 q/ha GM and 59.5 q/ha DM) obtained when component crops were sown mixed at full seed rate but it was at par with pure bajra treatment for green fodder yield (268 q/ha).

5. Evaluation of ragi genotypes for forage production under rainfed condition.

(A. S. Gill)

Fifteen ragi genotypes were evaluated for forage yields in second year. The crop was sown on July 28 in rows 30 cm apart with 30 kg N/ha a basal fertilizer dose. Nitrogen at 30 kg/ha was top dressed 30 days after sowing. The crop was harvested for green fodder yield on October 29.

Strain GE No. 1126 recorded the maximum green (395 q/ha) and dry matter (98.0 q/ha) yields. Next in order were GE NO. 1759 (385 q/ha GM and 94.2 q/ha DM) and GE NO. 1768 (385 q/ha GM and 93.5 q/ha DM).


(A. S. Gill)

The experiment was modified with addition of three more collections. There were five exotic collections of B. decumbens and two of B. brizantha in the trial. Indigenous line of B. decumbens was also included as a local check. The grass was planted in July 5th at a spacing of 65 cm x 50 cm. Basal fertilizer schedule consisted of 45 kg N and 30 kg P₂O₅/ha. Top dressing of 15 kg N/ha was done on August 5. The crop was harvested for green fodder on September 1st.
The genotypes tested did not register significant differences of both green fodder and dry matter yields. However, *B. decumbens* entry E. C. 145737 recorded highest green (243 q/ha) and dry matter (57.9 q/ha) yields giving 17.9 and 19.1% higher production than the local check.

3.5 **Forage production through crop and varietal blends selected on the basis of crop geometry and plant ideotype concept under optimal and sub optimal levels of management and environmental condition.**

(M. S. Raut and A. S. Gill)

1. Studies on relay intercropping of maize and cowpea.

The object of the study was to advance or delay the sowing of cowpea (Russian giant) in association with high yielding fodder maize (Vijay) to achieve maximum biomass production without jeopardising the yield of the individual component. Treatments consisted of maize sole at normal sowing (T1), cowpea sole at normal sowing (T2), two weeks before normal sowing (T3) and two weeks after normal sowing (T4), combination of T1+T2 (T5), T1+T3 (T6), and T1+T4 (T7) in randomised block design with 4 replications. Normal sowing date was July 4. Treatments T5, T6 and T7 had maize and cowpea 1:1 row system at a spacing of 40 cm. The experiment was harvested for fodder yield on September 11.

Planting cowpea two weeks before the sowing of maize (T6) in mixed cropping of paired row system resulted in maximum green (237 q/ha) and dry matter (41.5 q/ha) yields with LER of 1.47. The contribution of cowpea was 39.2 and 10.4 q/ha in terms of green and dry matter production, respectively.

Maximum cowpea production in the mixed cropping treatments was registered with treatment T7 (99.6 q/ha GM and 27.3 q/ha DM) with highest LER of 1.49 through the combined yields (130.8 q/ha GM and 31.4 q/ha DM) were comparatively low.

AG-3.5 **SOIL AND WATER MANAGEMENT RESEARCH ON FORAGE/PASTURE CROPS.**

4.1 **Crop water use and irrigation management.**

(Menhi Lal and N. P. Shukla)

1. Studies on water use pattern and irrigation requirement of promising oat Varieties.

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Three varieties of oat (JHO–813, JHO–816 and Kent) were evaluated at four moisture regimes (IW/CPE ratio of 0.5, 0.7, 0.9 and 1.1) in RBD replicated thrice with a view to study their water use pattern and developing suitable irrigation schedule for higher herbage production.

The result revealed that variety JHO–816 produced the highest green (390.8 q/ha) and dry matter (107 8 q/ha) yields. This variety was however, statistically at par with standard variety Kent in green matter production but proved significantly superior in dry matter accumulation. The differences in herbage production of Kent and JHO–813 did not reach the level of significance.

Increasing levels of soil moisture increased both green and dry matter yields with the result that irrigation at IW/CPE ratio of 1.1 gave significantly higher herbage accumulation (465.5 q green and 125.7 q dry matter/ha). The magnitude of increase was more conspicuous when moisture regime was increased from IW/CPE ratio of 0.9 to 1.1 as compared to its increase either from .5 to .7 or from .7 to .9.

Therefore, oat variety JHO–816 appeared to be very promising and the crop may be irrigated at IW/CPE ratio of 1.1 to provide suitable moisture environment for higher herbage production.

2. Response of lucerne varieties to irrigation regimes.

The response of three lucerne varieties (IGFRI–244, Anand–2 and Sirsa–9) to five levels of soil moisture (Irrigation at IW/CPE ratio 0.4, 0.6, 0.8, 1.0 and 1.2) was studied in RBD replicated thrice to work out optimum irrigation schedule for increasing crop productivity and water use efficiency.

The productivity of all lucerne varieties improved with subsequent cuttings and the maximum herbage accumulation was recorded in third cutting. Though the varieties did not differ significantly in total forage yields but IGFRI–244 produced the highest green matter of 293.4 q/ha and was followed by Sirsa–9 with a productivity level of 279 q/ha. There was practically no difference in dry matter yields of different strains as it varied within a narrow range of 69.8 to 73.5 q/ha.

Irrigation treatments showed significant effect and the yields increased with increasing moisture regimes up to IW/CPE ratio of 1.0 which recorded the highest green (340.5 q/ha)
and dry matter (84.6 q/ha) production. These yields were significantly greater than those obtained at IW/CPE ratio of .4 to .8. The magnitude of increase in dry matter accumulation also increased concurrently with moisture regimes upto a ratio of 1.0 yields in general and green matter in particular decreased with further increases in the level soil moisture to a ratio of 1.2.

Therefore, among the lucerne varieties evaluated IGFRI-244 holds promise for higher green forage production. The irrigation schedule in lucerne should consist of irrigating the crop at IW/CPE ratio of 1.0 to provide optimum moisture conditions for greater herbage accumulation.

3. Effect of depth and schedule of irrigation on water use efficiency and forage productivity of newly developed berseem varieties

The investigation was taken up with a view to assess the productivity and water use efficiency of newly developed berseem varieties. The treatments consisting of three berseem strains (IGFRI-99-1, JB-1 and BL-1) each under three depths (40, 60 and 80 mm) and schedules (45, 60 and 75 mm CPE) of irrigation were compared in 33 confounding cell.

Berseem variety IGFRI-99-1 (Wardan) produced the highest total green and dry matter yields at 707.3 and 140.4 q/ha respectively. This variety was, however, at par with BL-1 but significantly superior to JB-1 in green forage production. Similar was the trend with respect to dry matter accumulation though the differences were statistically not significant.

The irrigation depths varying from 40 to 80 mm did not bring out significant differences in forage yields. However, application of 60 mm water at each schedule appeared to be quite adequate. Irrigation at 45 mm CPE resulted in the highest green (721.9 q/ha) and dry matter (140.7 q/ha) production. Delaying irrigation to 60 and 75 mm CPE, however, caused significant reduction in green matter yield. The decrease in dry matter accumulation also followed the similar trend but the differences were statistically not significant.

Thus berseem varieties, IGFRI-99-1 (Wardan) holds greater promise and the crop needs to be irrigated at 45 mm cumulative pan evaporation–CPE with 60 mm water for achieving higher productivity and rationalizing water use.

4. Effect of soil moisture variations on forage yield and water use of different sorghum varieties.
In the present investigation four sorghum varieties (Pioneer, HD-2, J-69 and PC-6) were evaluated at three moisture regimes (rainfed, 50 and 75% ASM) in RBD replicated thrice to workout suitable moisture condition for exploiting their productivity potential.

The result indicated that the varieties Pioneer and HD-2 producing green matter yield of 381.2 and 376.0 q/ha respectively were at par between themselves, but significantly superior to PC-6 and J-69 which inturn did not differ from each other. In dry matter production, however, HD-2 registered significant lead over other strains. Moreover, HD-2 and Pioneer performed better than remaining varieties in so far as productivity per day was concerned. The relative leaf turgidity of PC-6 and J-69 were 93.7 and 87.0% whereas Pioneer and HD-2 exhibited almost similar values around 98%.

Maintenance of soil moisture at 75% ASM produced significantly highest green matter yield of 385.6 q/ha as compared to 50% ASM and rainfed conditions. Though the highest dry matter accumulation was observed with 75% ASM but it did not differ statistically from 50% ASM which inturn was at par with rainfed treatment indicating that the variation in soil moisture regimes exercised more pronounced effect on green matter production than on dry matter accumulation. Increasing moisture regimes improved the relative leaf turgidity with the result that the maximum relative water content was recorded with 75% ASM.

It is therefore, evident that sorghum varieties HD-2 and Pioneer possess the potential for high herbage yield and maintenance of soil moisture at 75% ASM is required to obtain increased yield of succulent forage.

5. Response of forage bajra to phasic moisture regimes.

The investigation was taken up with nine treatments comprising various combinations of sub-optimum (25% ASM), optimum (50% ASM) and super optimum (75% ASM) levels of soil moisturising establishment, vegetative and reproductive phases of crop growth to study the response of bajra to phasic variation in soil moisture regimes and to identify the critical stages to moisture deficit for herbage production.

The highest green (496.8 q/ha) yields were obtained when super optimum level of soil moisture was maintained throughout the crop growth period. This was, however, at par with moisture treatment involving super optimum–suboptimum combination corresponding to sequential growth phases in green matter yield but significantly superior to

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remaining treatments in so far as dry matter production was concerned. The herbage yields in general, were lower when establishment stage was subjected to sub-optimum level of soil moisture which could not be compensated with an increase in the moisture regime at subsequent growth stages of crop.

Thus bajra crop needs to be maintained under super optimum level of soil moisture during establishment and vegetative growth phases for realising maximum herbage production. Maintenance of moisture at optimum and sub-optimum levels may however be considered during reproductive stage to effect water economy in forage bajra.

4.3 : Evaluation of irrigation methods and soil management techniques for efficient water use.

(N. P. Shukla and Menhi Lal)

1. Response of different oat varieties to moisture under skip row and mixed planting techniques.

Three oat varieties (IGFRI-2681, Kent and HFO-114) sown in three different planting patterns (regular rows 25 cm apart, skipping of every 4th row and sowing mustard in skip rows) were subjected to three moisture regimes (IW/CPE ratio of 0.5, 0.8, and 1.1) in 33 confounding design with 3 blocks each accommodating 9 treatment combinations.

The result revealed that variety Kent producing 319.7 q green and 86.0 q dry matter/ha significantly cut yielded IGFRI-2688 and 114 which inturn were at par between themselves. Treatments involving regular planting of oat substituting skipped rows with mustard did not differ statistically between themselves but proved significantly superior to skip row planting in green matter production. The planting pattern however, did not cause significant change in dry matter accumulation.

Both green and dry matter yields increased with increasing levels of moisture and the highest production (310.5 q green and 78.0 q/dm/ha) was obtained by scheduling irrigation at IW/CPE ratio of 1.1 which was at par with a ratio of 0.8 but significantly superior to 0.5.

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Thus Oat variety Kent proved to be superior and planting in regular rows or substituting every 4th row with mustard appeared to be equally effective in herbage production. The crop may be irrigated at IW/CPE ratio of .8 to provide suitable moisture environment and economic water use.

2. Effect of crop resistance on water distribution and forage yield of oat under basin irrigation.

Oat varieties (OS-6 and OS-7) seeded in four planting patterns (lengthwise 25 cm apart rows, width wise 25 cm apart rows, cross sown 25 cm apart rows, and broadcasting) were evaluated to study the effect of degree of crop resistance on uniformity of irrigation water distribution and forage productivity.

Oat varieties did not differ statistically in green forage yield but OS-7 accumulated significantly higher dry matter as compared to OS-6. Significantly highest green (473.5 q/ha) and dry matter(135.0 q/ha) yields were obtained by cross sowing. The remaining planting patterns, however, showed no statistical variation in green forage yield. On the other hand, broadcasting produced significantly greater dry matter yield as compared to length-wise and widthwise sowings.

Therefore, Oat variety OS-7 proved better than OS-6 and cross sowing appeared to be an ideal sowing technique under basin irrigation for realizing higher herbage production.


The experiment was conducted with treatment combinations comprising three levels each of moisture regime (25, 50 and 75% ASM), fertilizer nitrogen (30, 60 and 90 kg/ha) and plant density (10, 15, and 20 kg seed/ha) in order to establish relationship among interacting factors of crop density soil fertility in determining water use pattern in forage bajra.

The result revealed that increasing the moisture regime from 25 to 75% ASM increased the herbage production. The highest green (285.9 q/ha) and dry matter (60.5 q/ha) yields were obtained with 75% ASM which were at par with yields recorded at 50% ASM but significantly superior to those at 25% ASM. Application of 90 kg N/ha yielded significantly higher green forage than 30 kg N/ha but the successive differences did not reach the level of significance. The effect of nitrogen was, however, not reflected significantly in dry matter accumulation. Though the variation in seed rate did not bring out significant differences in herbage yield but the
highest green and dry matter yields were obtained with 20 kg seed/ha. This was followed by a seed rate of 15 kg/ha. Therefore, bajra crop may be sown at 15 kg seed rate/ha, fertilized with 50 kg N/ha and irrigated at 75% ASM for higher forage yields.

4. Response of cowpea varieties to supplemental irrigation and phosphate fertility.

Cowpea varieties IGFRI-450 and NP-3 were evaluated at three soil moisture regimes (rainfed, 50% and 75% ASM) and four levels of phosphate (0, 30, 60 and 90 kg P₂O₅/ha) in randomised block design with three replications in two separate sets of experiment.

The highest green (250.4 q/ha) and dry matter (50.2 q/ha) yields of variety IGFRI-450 were observed with irrigation at 75% ASM, which was significantly superior to rainfed treatment (226.7 q green and 45.6 q DM/ha). There was a significant linear response to phosphate application up to 90 kg P₂O₅/ha in terms of green matter production. However, the dry matter yield was significant only at 90 kg P₂O₅/ha. The differences between 60 and 30 kg P₂O₅/ha were statistically not significant.

The effect of soil moisture regimes on green forage yield of variety NP-3 was statistically not significant. However, the dry matter yield at 75% ASM (67.5 q/ha) was significantly higher over 50% ASM (60.9 q/ha) which in turn proved significantly superior to rainfed treatment. The response to phosphate was only up to 60 kg P₂O₅/ha. Further increase in phosphate level to 20 kg P₂O₅/ha did not increase green and dry matter yield significantly. The green matter production at 0, 30, 60 and 90 kg P₂O₅/ha were 195, 294, 350.6 and 367.6 q/ha respectively. The corresponding dry matter yields were 37.6, 59.6, 68.0 and 73.1 q/ha.

Thus, it is evident that the response to moisture regime continued up to 75% ASM with both varieties. On the other hand, the response to phosphate was observed up to 90 kg with IGFRI-450 and only up to 60 kg P₂O₅/ha with NP-3.


(Menhi Lal & N. P. Shukla)

The irrigative values of sewage, cattleshed washings, saline and canal waters were evaluated under light red and medium black soils taking berseem, lucerne and metha as test crops during rabi 1984–85.
The result revealed that the productivity of all the crops remained higher in medium black soil as compared to light red soil irrespective of type of irrigation water. The productivity order was berseem > metha > lucerne under both the soil environments. On the basis of green and dry matter accumulation the performance of different quality of irrigation water could be indicated as:

Light red soil: Sewage > Cattleshed wash > Canal water > saline water

Medium black soil: Sewage > Canal water > Saline water > Cattleshed wash

These observations, therefore, indicated that the response to sewage irrigation was better both under light and medium type of soil whereas cattleshed wash showed good irrigative value under light soil conditions.

The cropwise performance of different types of water under light red soil could be as:

Berseem: Sewage > Canal water > Cattleshed wash > Saline water
Lucerne/Metha: Sewage > Cattleshed wash > Canal water > Saline water.

However, under medium black soil the trend remained the same for all the crops i.e, Sewage > Canal water > Saline water > Cattleshed wash.

There is also indication that berseem is susceptible to fresh cattleshed washing whereas all the crops showed susceptibility to saline water irrigation.

Therefore, sewage holds promise for irrigating berseem, lucerne and metha under both the types of soils whereas cattleshed washing may be considered for irrigating lucerne beneficially under light red soil conditions.

AG-5: EVALUATION OF FORAGE AND PASTURE MODELS.

5.1 Modeling of forage farming systems with ideotype selection, crop geometry and defoliation/cutting technology with special reference to forage crops.

(R. K. Pandey and Fateh Singh)
1. **Evaluation of barley varieties alone and in combination with mustard under variable crop geometry systems for higher fodder production.**

This was the commencing year of the experiment. The objective was to workout the barley based fodder production system. Barley, Cv. Jyoti, Ratna and exotic strain were grown in (1 : 1 : 1 row system and also under broadcast sowing by blending 1/3 seed of each variety. In mixed cropping, the broadcast mustard Cv. China cabbage was superimposed by 25 cm apart rows barley in one case and both the crops grown in alternate paired rows, in another. For comparison their pure culture crops were a so maintained at 25 cm row spacing. In all twelve treatments were tried in randomised block design with three replicates.

The maximum mixed fodder yield was recorded when barley Cv. Ratna was grown with mustard in paired rows. This system supplied a reasonable fodder component of mustard (27 q/ha) in the mid of the season. This combination appeared to be the positive one as its mixed fodder yield (68.5 q/ha) was more than their mean yield from pure culture crops (45.4 q/ha). However, the treatments involving the sowing of all the three barley varieties in lines or mixed seed sowing and broadcast mustard with Ratna and exotic strain closely followed the above system. The highest contribution of mustard in the broadcast treatment with exotic barley indicated its aggressiveness over the associated crop. There was no significant difference among the barley varieties.

2. **Evaluation of mixed cropping of oat + lucerne in relation to different oat genotypes for higher fodder production.**

This was first year of the experiment. The objective of the study was to select suitable oat ideotype for mixed cropping with lucerne. Four varieties of oat, viz-IGFRI-3021, IGFRI-2688, OL-125 and UPO-136 were tested in combination with lucerne Cv. IGFRI-244. For comparison, their soil cropping treatments were also included. In crop mixtures, broadcast lucerne (15 kg seed/ha) was immediately followed by 50 cm apart row crop of oat. Thus nine treatments were tested in randomised block design with three replicates.

The first cut of oat + lucerne was taken at 75 days of growth and second cut at the flowering stage of oat. Amongst mixed cropping the highest mixed dry matter yield of 90.4 q/ha was obtained with oat-OL-125 + lucerne. This incorporated maximum legume component of 24.3 q/ha This combination was however at par with oat-IGFRI-3021 + lucerne. None else combination superseded the above two systems.

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Selection of suitable ideotypes for mixed cropping of forage cereals and legumes.

This was the second year of the experiment. The objective was to work out the mixed cropping system for improved legume rich fodder production. Twelve systems were evaluated in randomised block design with three replicates.

The maximum mixed dry matter yield of 81.0 q/ha was recorded under the system where sorghum PC-6 was combined with the annual Sesbania and cowpea. The above system incorporated the legume fodder of 29.1 q/ha. The other combinations yielded lower than this system.


This was the second year of the study. The objective was to have the ideotypes for better legume rich fodder production system. In all twelve cropping systems were tried in randomised block design replicated three times.

None of the crop combinations appeared to be significantly superior over the cropping system consisting of bajra (Rajko)+Cowpea (HFC-42-1) both in respect of mixed fodder yield and legume component. The system produced the total dry matter yield of 67.2 q/ha including 13.0 q/ha legume.

5. System analysis of multiproportional blending of cereals and legumes for quality fodder production.

This was the second year of the study. The objective was to synthesise a sorghum based system of compatible crops for quality fodder production. Nine treatments were compared in randomised block design with three replications.

All the mixed cropping treatments were marked to be at par with 25 cm apart row crop of M. P. Chari (check), Mixed sowing of M. P. Chari+bajra+maize+teosinte+Cowpea+Guar+Sesbania was found to be an ideal combination. This cropping system apart from maintaining the production level also incorporated more legume component (14.7 q/ha of legume dry matter) which additionally enriched the fodder. The legume contribution was only from cowpea and Sesbania as the guar and sunhemp could not survive due to their non compatibility in the system.

6. System analysis of Deenanath grass with the genotypes of cowpea for improved quality biomass production.
It was the second year of the study. In all nine treatments were tried in randomized block design with 3 replications.

None of the crop mixture was found to be significantly superior to sole cropping of Deenanath grass (74.1 DM q/ha). However, the maximum mixed dry matter yield (80.4 q/ha) was recorded when Deenanath grass was combined with broad cowpea (NP-3). This cropping system incorporated the highest proportion of legume: fodder (26.0 q/ha) and appeared to be significantly perior over rest of the combinations.

5.2: Modelling of forage farming systems with ideotype selection crop geometry and defoliation technology with special reference to continued forage tree cropping along-with crop production.

(A. S. Gill)

1. Studies on intensive forage production system under continued tree cropping.

This was the second year of the trial. During the period under report five cuts were taken for green fodder.

The results clearly indicated the superiority of planting Leucaena intercropped with hybrid napier variety IGFRI-3 which gave the maximum green (1947 q/ha) and dry matter (442 q/ha) production. This combination had also given the maximum biomass production during the first year of the investigation. Next best treatment was pure planting of hybrid napier IGFRI-3 (1887 q/GM and 445 q/DM/ha).

2. Planting techniques of Leucaena and hybrid napier for higher biomass production.

This was the first year of the investigation. The objective of the experiment was to establish the correct technique of planting. Leucaena and hybrid napier to achieve maximum production per unit area per unit time. Treatments consisted pure planting of Leucaena K-8 (T₁) and hybrid napier IGFRI-3 (T₂) at a spacing of 50 cm x 50 cm. Intercropping of Leucaena and hybrid napier was done in 1 : 1 ratio with planting of both the components in the same rows (T₃), in alternate rows (T₄) and in paired rows (T₅). Intercropping was also done in 2 : 1 (T₆) and 1 : 2 (T₇) ratio of Leucaena and hybrid napier, respectively. In all 7 treatments were evaluated in randomised block design replicated three times. Planting was done on July 24. Leucaena was directly seeded and rooted slips of hybrid napier were used. Basal fertiliser schedule comprised 30 kg N+50 kg P₂O₅/ha followed by top dressing of 30 kg N/ha. During the period under report only one cut was taken on November 6.
Maximum green (261 q/ha) and dry matter (65.8 q/ha) yields were registered with *Leucaena* and hybrid napier in 1:1 ratio. The next best treatment was planting *Leucaena* and hybrid napier in 1:1 ratio. Under intercropping treatments maximum production of *Leucaena* and hybrid napier components was achieved by planting *Leucaena*+hybrid napier in 2:1 ratio and *Leucaena*+hybrid napier in 1:2 ratio, respectively.

3. **Selection of a suitable cereal fodder crop under continued tree cropping.**

This was the second year of the investigation. During the period under report after the tree was cut for fuel, five cuts were registered from the perennial cereal fodder crops.

The study indicated that maximum fuel production (375 q/ha) was registered under pure tree plantation. Highest forage production was obtained with pure planting of hybrid napier. Interestingly highest per plant yield of hybrid napier was achieved by planting in association with trees. Taking into consideration the monitary benefits highest gross return was noticed in pure planting of hybrid napier closely followed by pure planting of guinea grass and tree+hybrid napier combination.

**AG–6 : AGRO–FORAGE FORESTRY PRODUCTION SYSTEM**

**6. 1 : Evaluation of different forage forestry pasture systems with introduction of legume.**

(Fateh Singh)

1. Evaluation of forage forestry system with the introduction of legume including browses.

This was the fifth year of the trial. The treatments comprised seven tree species interplanted with the three nourishing legumes and one control. The study indicated that the natural grasses proved to be remunerative without having any adverse effect on the growth of *Acacia*. Grass production in association with *Acacia* (28.5 q/ha DM) and without tree component (36.7 q/ha DM) were found to be at par. In addition to grass yield an additional yield of fuel (16.5 t/ha) and leaf fodder (0.84 q/ha) was registered with *Acacia*.

2. Feasibility of various intercrops with Anjan grass.

This was the first year of the trial. Treatments comprised pure grass (anjan); grass + range legumes *Stylosanthes hamata*, *Stylosanthes scabra*, *Stylosanthes viscosa*; grass + annual leguminous fodder crops (*Sesbania*/*cowpea*) and grass + annual cereal fodder crops (*maize/sorghum/pearl millet/Denanathan grass*). In all ten treatments were evaluated in rai domised
block design with three replications. Grass seedlings were transplanted on July 1 at a spacing of 50 cm x 20 cm and one row of the intercrops was sown in between the grass rows on July 5. Basal fertilizer schedule comprised 60 kg N and 40 kg P$_2$O$_5$/ha.

The highest dry forage yield (43.6 q/ha) was achieved with grass + maize followed by grass + *Sesbania* (43.5 q/ha). Association of *Sesbania* with grass producing a dry matter yield of 19.8 q/ha could be preferred over the treatment which gave the highest forage yield but both the components were non-leguminous in nature.

3. **Effect of nitrogen and phosphorus on the forage yield of *Cenchrus setigerus***.

This was the first year of the trial. The treatment combinations comprised 4 levels of nitrogen (0, 30, 60 and 90 kg/ha) and 3 levels of phosphorus (0, 40 and 80 kg P$_2$O$_5$/ha) in randomised block design with three replications. The grass seedlings were transplanted on July 8 with a spacing of 50 cm x 20 cm. Half the dose of nitrogen and full dose of phosphorus were applied as basal. The remaining dose of nitrogen was topdressed after one month of transplanting.

Application of nitrogen upto 30 kg/ha significantly increased the dry matter yield (26.6 q/ha). Phosphorus application however had no significant effect on the dry matter yield of grass under rainfed condition.

6.2: **Investigation on the integration of appropriate fodder crops in food/cash crop rotations and as intercrops.**

(A. S. Gill)

This was the second year of the study. Thirteen wheat varieties were grown in two separate set of experiments under the agroforestry system as well as under open system. The sowing was done in the last week of November in both the cases in rows 25 cm apart with 100 kg seed/ha. Fertilization comprised 120 kg N + 45 kg P$_2$O$_5$ + 30 kg K$_2$O/ha.

Under the agro-forestry system, wheat variety Raj 1555 gave the best performance (45.95 q/ha) followed by WH-147 (42.95 q/ha). Under open system variety DWL-5023 registered the maximum yield (47.79 q/ha) and was followed by variety WH 147 (47.29 q/ha) and Raj. 1555 (47.12 q/ha).
DIVISION OF SOIL SCIENCE

SS-1 : SOIL FERTILITY AND PLANT NUTRITION STUDIES UNDER INTENSIVE FORAGE CROPS ROTATIONS.

1. Effect of N on the yields of different intercropping systems under varied P application.
   (S. B. Tripathi and C. R. Hazra)

   The field experiment was undertaken during rabi, kharif and summer seasons to work out the contribution of intercropped legumes to the total forage productivity of Hybrid napier against its pure stand under varying levels of N application (0, 50, 100 and 150% of recommended dose of 240 kg/ha/year to hybrid napier-40 kg N/ha after each cut. Berseem senji and pea were included as intercrops during rabi and cowpea, guar and sunhemp were tried during summer and kharif seasons.

   The result indicated that the maximum forage production was recorded with napier + berseem during rabi, napier + cowpea during summer and napier + sunhemp during kharif. Napier with berseem and cowpea in two seasons was found to be most productive intercropping system. The intercropping increased the yield by 20-25% over pure cropping of napier bajra hybrid.

2. Forage yield of Napier-bajra hybrid, berseem and cowpea in intercropping as influenced by P application.
   (C. R. Hazra and S. B. Tripathi)

   A field experiment was conducted with napier bajra hybrid with cowpea in both summer and kharif and berseem in rabi. The crop was fertilized with 60, 120 and 180 kg P2O5/ha applied in one, two and three seasons in various combinations against a control treatment. In all, there were eight treatments replicated three times in R. B. D. The expe-
rimental results indicated that the highest forage yield during winter (87.9 q/ha) and rainy season (139.5 q/ha) was associated with 180 kg P₂O₅/ha in three equal instalments in each of the seasons. Application of phosphorus at 180 kg P₂O₅/ha in equal instalments over three seasons and at 120 kg P₂O₅/ha in two instalments during rainy seasons produced similar yields. The overall productivity of the crop on yearly basis indicated that the highest forage yield was associated with 180 kg P₂O₅/ha (350 q/ha) followed by 120 kg P₂O₅/ha during winter and rainy season @ 60 kg in each season (285 q/ha) and 120 kg P₂O₅ @ 60 kg/ha during summer and rainy season (271 q/ha) and 120 kg P₂O₅/ha during winter and summer @ 60 kg/ha in each season (265 q/ha).

3. Effect of organic and fertilizer N on forage production of Napier-bajra hybrid.

(S. B. Tripathi & C. R. Hazra)

The objective was to reduce and economise the use of fertilizer N substituting through organic N sources, as napier bajra hybrid is a high N requiring perennial crop. The treatments consisted of nitrogen (100%) application through urea alone, (50%) substitution by organic source such as castor cake, neem cake mahuwa cake and FYM on N equivalent basis. A control plot (without N) was also included for comparison.

The highest forage yield was obtained with urea + mahuwa cake on 50% ; 50% basis at full N dose and was followed by urea + castor cake sources. The efficacy of different cakes when applied at 50% N equivalence as substitute to urea N was of the order of mahuwa cake and FYM (96%), castor cake (90%) and neem (87%), against urea N (100%).

4. Herbage yield of different intercropping systems under varied and time of P application.

(C. R. Hazra and S. B. Tripathi)

The experiment was conducted with cereal forage crops viz., maize, sorghum and pearl millet alongwith cowpea as intercrop. There were two sets of treatments (1) uniform rows with alternate planting of one row of cereal + one row of legume at 30 cm spacing (50% + 50%) and the other set in paired rows i, e, two rows of main crop at 20 cm with one row of legume in 40 cm interspace between two pairs (100% + 50%). The application was superimposed on the intercropping treatments @ 40 kg P₂O₅/ha to cereals and 80 kg P₂O₅/ha to legume. The pure cropping of all the crops received recommended dose of phosphorus.

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The study indicated that the paired row with 150% plant population had an yield advantage of about 3.7 q/ha of dry forage over uniform rows (100% population). All the intercropping systems have higher LER values (1.19–1.35) than pure cropping. The highest LER value was associated with maize+cowpea (2:1) in paired row planting with 80 kg P₂O₅/ha.

5. Effect of N through different sources with and without P on forage yields and N & P uptake by cowpea and oats (Pot experiment).

(S. B. Tripathi and C. R. Hazra)

The experimental treatments included Urea, FYM and neem cake as N-sources alone and in combination with single superphosphate (SSP). In addition to their six combinations, urea was combined with FYM and neem cake on 1:1 basis for making N dose along with SSP. Sulphur urea was also included as nitrogen source. The nutrient doses consisted of 30 kg N/ha for cowpea, 120 kg N/ha for oats and 80 kg P₂O₅/ha to both the crops. The highest yield of cowpea was observed with Urea+FYM+SSP (48.6 q/ha of dry forage) followed by Urea+neem cake+SSP (46.6 q/ha) and Urea+SSP (42.4 q/ha). All these three treatments significantly out yielded the remaining ones. The highest yield of oats obtained with Urea+FYM+SSP (107.7 q/ha) was significantly superior to Urea+SSP (94.9) and FYM+SSP (78.2). The yield was greatly improved with Urea+neem cake+SSP (99.5 q/ha) over N through single source e.g. Urea+SSP (94.9 q/ha) and neem cake+SSP (88.4 q/ha). The N and P uptake by both the crops were closely related to their yields.


(S. B. Tripathi and C. R. Hazra)

The treatments included FYM and urea as organic and inorganic sources at 50% and 100% level of recommended dose with and without P. In addition, two treatments FYM (50%)+urea (50%) with and without P were included with absolute control. The recommended doses of N for cowpea and oats were 30 and 120 kg N/ha respectively. The P level was 8C kg P₂O₅/ha for both the crops.

The highest forage yield of cowpea was obtained from full dose of N from organic and inorganic sources on 50% : 50% basis together—with P application. This
was followed by application of N at full dose through urea+SSP. The P application at full dose of N through both sources gave additional yield of about 29 per cent. The N and P uptake was closely related to forage yields. The P uptake was almost twice in plots receiving full N through urea and FYM or urea. The highest yield of oats was obtained with FYM+urea (50:50) +SSP (96.6 q/DM/ha). This has resulted in increase of 30% yield over FYM—Urea (50 : 50) which in turn produced higher yield than urea (100%) alone. The N and P uptake followed the pattern of forage yield.

7. Effect of N fertilization with and without sulphur on forage production of chinese cabbage.

(S. B. Tripathi and C. R. Hazra)

Field experiment was undertaken with four levels of N (0, 20, 40 and 60 kg N/ha) and two levels of sulphur (0 and 40 kg S/ha).

The result indicated that the application of nitrogen and sulphur separately increased the forage yield of chinese cabbage as compared to control treatment (without N & S). The green and dry fodder yield as well as S content was significantly higher when 40 kg N/ha was applied with 40 kg S/ha as compared to 60 kg N/ha alone. Nitrogen and sulphur contents were also found to increase significantly with combined application of 60 kg N/ha and 40 kg S/ha.

8. Green forage, dry forage and seed yield of barley as influenced by N and preceding crop.

(C. R. Hazra & S. B. Tripathi)

The field experiments were undertaken in split plot design with kharif crops as main plot and N levels as sub-plot treatments. The main plot treatments included three viz., sunhemp, cowpea and fallow and sub-plot treatments had five nitrogen levels viz., 0, 10, 20, 30 and 40 kg N/ha. The green and dry forage yields were recorded at 50% flowering. A separate experiment was conducted with similar treatments for barley seed yield. The studies indicated by legume crops were always higher than that the fallow plots under all levels of N application. Under control treatment barley yielded about 3.8 and 4.7 q/ha of additional dry forage when preceded by cowpea and sunhemp, respectively. The highest
benefit in N gain was equivalent to 5–6 kg N/ha. Sunhemp had better effect in improving grain yield than cowpea. The benefit from sunhemp and cowpea legumes as preceding crop was to the tune of about 30 kg N/ha.


(C. R. Hazra and S. B. Tripathi)

A field experiment was conducted to find out the effect of preceding crop on herbage yield and nitrogen requirement of maize crop. The preceding crops included forage cowpea, green manuring of cowpea and summer fallow. The nitrogen levels were 0, 25%, 50%, 75% and 100% of recommended N-dose (120 kg N/ha). The experiment was conducted in splitplot design with preceding crops in main plots and N-levels in sub plots. The study indicated that maize crop significantly responded to 120 kg N/ha preceding by fallow or forage cowpea. However, the response was limited to 90 kg N/ha when preceded by green manuring of cowpea. The order of productivity was green manuring fallow plots. The average response was 29, 33, 34 and 28 kg dry forage per kg N with 25%, 50%, 75% and 100% N application. The average N contribution by green manuring forage cowpea was 35 and 13 kg N/ha, respectively.

10. Performance of different varieties of winter maize for forage production at different sowing dates in red soils.

(C. R. Hazra and S. B. Tripathi)

Five winter maize varieties were tested in red soils at three different sowing dates. The green and dry forage yields indicated that Manjri composite was the most productive variety as this variety maintained highest yield at all the sowing dates. All the varieties except this yielded the highest forage with November sowing (30.11.84) followed by mid November (15.11.84) and least with mid December (15.12.84) sowing. The relative dry forage yields of different varieties were of the order of Manjri composite (100%), Manjri (89%) Gene pool (80%), Jaunpuri (79%), Tlnpaklia (77%).

11. Performance of different winter maize varieties at different sowing dates—effect on grain yield.

(S. B. Tripathi and C. R. Hazra)
Five varieties of maize were tested during winter season of 1984-85 under different sowing dates viz. 15-11-84, 30-11-84, 15-12-84 and 30-12-84 in factorial R. B. D. The study indicated that all the varieties gave higher grain yield when sown in November and the productivity gradually decreased with the late planting during December. The planting during mid November also gave higher grain yield than mid and late December planting. Among different varieties Manjri composite gave 3.24 to 4.58 q/ha higher yield as compared to other varieties with all the sowing dates.

12. Nitrogen response to herbage yield of different winter maize varieties.

(S. B. Tripathi and C. R. Hazra)

The field experiment was conducted with five varieties of winter maize at four levels of nitrogen viz. 0, 40, 80 and 120 kg N/ha. All the five varieties responded upto 120 kg N/ha. The average response per kg of N was of the order of 37, 43 and 35 kg with the application of 40, 80 and 120 kg N/ha, respectively. Amongst the different winter maize varieties, the highest yield was recorded with Manjri composite. The relative yield from different varieties were of the order of Manjri composite (100%), Manjri (88%), Tinpakhia (85%), Gene pool (85%) and Jaunpuri (83%).

1.4.1 Studies on bacterial mediated N-fixation for increased productivity in cultivated fodder crops.

(M. R. Pahwa)

1. Effect of inoculating different densities of \textit{Rhizobium trifolii} on nodulation, growth and fodder yield of berseem.

The present investigation aimed at determining the optimum inoculum load for increased nodulations and forage productivity of berseem. In a pot experiment using medium black soil (pH-7.2) berseem seed inoculation was tried at five cell densities (0, 1.5 x 10^2, 1.5 x 10^4, 1.5 x 10^6 and 1.5 x 10^8 cells/ml inoculum). The result revealed that a population density of 1.5 x 10^5 cells/ml inoculum significantly increased nodulation, root length as green and dry matter accumulation.

2. Efficiency of \textit{N}_2-fixers in relation to some plant nutrients.

(90)
It is well established that effectiveness of \( N_2 \) fixation can remarkably be improved by providing optimal level of specific plant nutrients. Separate studies were conducted in lucerne, berseem, pearl millet and oat crops using red soil (pH-8.20) for finding out the appropriate concentration of Zn and S under inoculated conditions. Graded level of these plant nutrients were tested in presence and absence of \( N_2 \)-fixers. The results from these studies are as follows:

(i) Application of 20 kg Zn SO\(_4\)/ha along with *Rhizobium* significantly increased nodulation, root length, green and dry matter yields of lucerne in three cuttings.

(ii) The combined effect of 20 kg S/ha and inoculation produced significantly higher number of nodules (17/plant), root length (20.3 cm) in first cutting and total green (26.2 g/plant) and dry matter (3.7 g/plant) yields of berseem in three cuttings.

(iii) Interaction between Zn SO\(_4\) and *Azotobacter* culture was significant and the highest green forage yield of pearl millet was obtained at 10 kg Zn SO\(_4\)/ha. *Azotobacter* population of the rhizosphere of the inoculated oat plants was observed to be higher (\(5 \times 10^4\) cells/g of soil) as compared to uninoculated control (0.08 \( \times 10^4\) cells/g).

Beneficial effect of *Azotobacter* culture in increasing green and dry matter yields of oat was found to be the highest with 20 kg Zn SO\(_4\)/ha. The average increase in green forage yield due to inoculation was observed to be 14.3%. This treatment also recorded the highest *Azotobacter* count in the rhizosphere.

3. Selection of compatible cultivars of cereal and legume forages with respect to *Rhizobium/Azospirillum brasilense*.

The investigation was taken up both in microplot and pot culture and the significant findings are as under.

(i) Anand-2 lucerne showed superior performance over other strains.

(ii) Out of the twelve cultivars of berseem tested, only five (JB-2, JB-4, BL-38, 99-1 and Mescavi) responded significantly in terms of nodulation, root length and green/dry matter yields rhizobial culture. Highest per plant green matter (16.7 g) was obtained with variety 99-1 (Wardan), while highest number of nodules per plant was
observed in variety Mescavi *Rhizobium* symbiotic system (1st cut-9, 2nd cut-21 nodules/plant).

(iii) Among nine cultivars of pearl millet evaluated, P-2589, Giant bajra, Rajkoo, JFB-822, JFB-819 and P-53 exhibited significantly higher plant height, green and dry matter accumulation with *Azospirillum* inoculation. The highest forage yield was obtained by giant bajra/*Azospirillum* association.

(iv) HD-3 and M. P. Chari among the sorghum varieties responded significantly to *Azospirillum* inoculation. However, M. P. Chari appeared to be the most compatible host genotype for *Azospirillum* association as it showed higher number of *Azospirillum* cells in rhizosphere ($6.0 \times 10^4$ cells/g soil).

(v) Screening studies involving ten cultivars of winter maize (J-684, Manjri composite, Manjri, Tinpakhia, J-660, Deccan-103, African tall, Koth-83, J-2006 and Vijay composite) revealed superior compatibility of Manjri composite with *Azospirillum* in terms of forage productivity.

4. Response of forage crops to single or combined inoculation of *Azospirillum brasiliense* and *Azotobacter chroococcum*.

Investigations undertaken on sorghum, barley and oat for fodders under pot/microplot conditions were aimed to know (i) the efficiency of *Azospirillum* inoculation with and without urea on the forage yield (ii) optimum level of nitrogen in regard to effectiveness of N$_2$-fixation and (iii) the extent of saving in nitrogen by the inoculant. The recommended levels of P and K were uniformly applied to all the plots/pots. The results of these studies are given below:

(i) Seed inoculation of *Azospirillum* without nitrogen brought about significant increase in green forage yield of oat (24.3%). Inoculation effects on oat were significant at low levels of N (0 to 40 kg N/ha). The increase in fodder yield of oat by inoculation with 40 kg N/ha was approximately equivalent to that obtained with 60 kg N/ha without inoculation. Inoculation alone was observed to increase R:S ratio of *Azospirillum* cells to 70 (control soil-$0.04 \times 10^4$ cells/g; 1-Rhizosphere $2.8 \times 10^4$ cells/g).
(ii) Twenty four treatments comprising 12 levels of nitrogen (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 and 110 kg N/ha) with and without *A. brasilense* inoculation were tried on fodder sorghum. Significant improvement in green forage yield was obtained due to nitrogen as well as with inoculation. Interaction between N and I was not significant. A saving of 30 kg N/ha was comparable to inoculation + 60 kg N/ha. The efficacy of the inoculum was found to be optimum at 60 kg N/ha (17% more green matter yield which recorded the highest number of *Azospirillum* cells in the rhizosphere ($21 \times 10^4$ cells/g soil).

(iii) Green and dry matter forage yields of barley and sorghum were significantly influenced up to 90 kg N/ha and seed inoculation by *Azotobacter chroococcum*.

Inoculation revealed a saving of about 15 kg N/ha in sorghum as comparable green and dry matter accumulation was noticed at 30 kg N/ha with inoculation and 45 kg N/ha alone. The rhizosphere *Azotobacter* count was the highest with inoculation 30 kg N/ha ($3.9-8.5 \times 10^4$ cells/g soil) in both the crops. The rhizosphere soil ratio of the uninoculated barley crop in respect of *Azotobacter* count was 5 whereas for M.P. Chari it was 7.

(iv) Investigation on the associative effect of inoculation of *Azospirillum brasilense* and *Azotobacter* on the forage yield of sorghum indicated 22.4% higher yield in soil (pH 8.20). The data revealed a saving of about 15 kg N/ha as green matter yield by 45 kg N/ha (283 q/ha) was almost equivalent to that obtainable with 30 kg N/ha + inoculants (290 q/ha). Graded level of nitrogen however, showed depressing effect on the efficacy of mixed inoculant.

5. Symbiotic efficiency of *Rhizobium* strains of *Leucaena leucocephala* and *Acacia* on fodder cowpea.

Invasive capacity of tree legume *Rhizobium* strains on cowpea was tested under pot conditions. Among the seven different types of culture (control, cowpea *Rhizobium*, *Rhizobium loti*-TAL-582, R-1oti, JAL-11582, LL-28-2, Acacia R-9, Acacia R-3) tried, maximum stimulatory effect on nodulation (15/plant) green and dry matter accumulation was observed with *Rhizobium* loti TAL-582. Inoculation with *Acacia* strains failed to produce any significant effect.

The roots of *Leucaena leucocephala* are known to inhibit the growth of *rhizobia*. Thus, studies in pots were initiated on fodder sorghum and lucerne with a view to examine the efficiency of bacterial N$_2$-fixer (*Azotobacter, Azospirillum* and *R. meliloti*) in terms of forage productivity under subabool (leaf extract and leaf litter addition) amended soils. Subabool leaf extract was used at four levels (0, 2.5, 5 and 10%) prepared by autoclaving dried leaf powder at 15 lbs for 15 minutes. The results are discussed below.

(i) Application of 10% leaf extract along with *Azotobacter* culture produced significant higher green and dry forage yields of sorghum.

(ii) In lucerne the stimulatory effect was observed only on root growth. Significant reduction in green and dry matter accumulation at all the levels of extract treatment. This trend was also reflected on nodulation.

(iii) Incorporation of dried subabool leafy material (5.1% N) up to 5 t/ha, as well as inoculation with *Azospirillum brasiliense* showed positive influence on green and dry matter yields of M. P. Chari. Interaction between subabool amendment and inoculation was significant. The highest forage production was exhibited by the combined treatment of subabool at 5% and inoculation.

4.2 Improving forage productivity and efficiency of indigenous rock phosphates through phosphate solubilizing microorganisms.

(M. R. Pahwa)

1. Isolation and distribution of phosphorus solubilizing microorganisms in soils.

Representative soil samples from different cultivated fields were drawn from a depth of 15 cm. The population of phosphate solubilizing microorganisms was estimated by dilution plate technique using modified Sikovskaya's medium. The bacterial and two fungal colonies (exhibiting relatively larger clearing zones in plate) were isolated from each of the red (rakar) and medium black (kabar) soils.

In red soil (neutral pH), P-solubilizing microorganisms were found to be $11 \times 10^9$/g dry soil while in case of medium black soil its population was $40 \times 10^9$/g dry soil. Bacterial were the dominant group of solubilizers in both the soils followed by fungi.
2. Growth and fodder yield of sorghum and oat as influenced by phosphate solubilizing microorganisms and type of rock–phosphates.

Oat: Five different types of inorganic phosphates (single super phosphate, Mussoorie rock phosphate, Udaipur rock phosphate, Laccadive and Vishakhapatnam phosphates) were tried at two level of P application (0 and 150 kg P\(_2\)O\(_5\)/ha) in red soil in presence and absence of phosphate solubilizing culture, *Pseudomonas streata*. The seeds were uniformly applied with the suspension of *Azotobacter* cells. phosphobacterized seeds alone resulted in 30% more green forage yield over uninoculated control. Superior performance in respect of green and dry forage yields in oat was exhibited by Mussoorie rock phosphate P solubilizing bacterial culture treatment. The positive influence on forage production may be due to the increased utilization of phosphate in this type of rock phosphate by the phosphate solubilizer.

Sorghum: Treatments were kept the same as tried in oat. Seeds were bacterized with *Bacillus polymyxa* H6. The pot culture experiment was terminated after 75 days. Mussoorie rock–phosphate–phosphate solubilizing culture combination ranked first in improving plant height green and dry matter production.

SS–I–6 : MICROMETEOROLOGICAL STUDIES IN FORAGE INTERCOPPING SYSTEM.

6.1 Oat intercropping system—Influence of legume and direction of planting herbage yield.

(Pradeep Behari & C. R. Hazra)

The experiment was laid out in factorial R B D with Oat as main crop combined with three legumes viz, pea, senji and lucerne in replacement series with row proportion of 1 : 1. Thus the crop combinations were Oat–pure, Oat+pea, Oat+Senji and Oat+lucerne. The directions were SE–NW, E–W, NE–SW and N–S.

The experimental results indicated that the highest green and dry forage yields were recorded with pure Oat (563.4 q green and 123.6 q dry matter/ha) and followed Oat+pea (502.9 q green and 115.3 q DM/ha). Amongst the directions, highest yield was obtained from SE–NW (564.4 q green and 129.9 q DM/ha) followed by E–W (490.0 green and 111.0 q DM/ha). 

(95)
DM/ha. The order of PAR availability to intercrop surfaces at harvest was only about 74% on pea, 47% on senji and 22% on lucerne.

6.2 Forage yield of maize and total herbage yield as influenced by different legume intercrops.

(Pradeep Behari & C. R. Hazra)

A field experiment was conducted with 11 treatment combinations consisting of maize pure in uniform row of 45 cm and maize in paired row of 30 cm with interspace of 60 cm in between two pairs. Maize at uniform and paired rows were combined with three legumes cowpea, clusterbean and sunhemp. In case of paired rows two levels of populations were tried for intercrops—single row with 50% population and two rows with 100%. In case of uniform maize rows, single alternate row of intercrop at 100% population was maintained.

The study indicated that the maize in uniform or paired rows had no significant yield difference. The maize yield under all the intercrops were lower than the pure crop of maize both under uniform and paired row planting systems. However, all the intercrops have more than compensated the loss of maize yield in associative cropping. The total forage productivity under all intercropping systems significantly higher than the pure maize yield. The increases in yield due to intercropping were 5.4% with cluster bean, 22.8% with sunhemp and 24.8% with cowpea.

6.3 Forage yield of pearl millet and total herbage yield as influence by different legume intercrop.

(Pradeep Behari & C. R. Hazra)

A field experiment was laid out with 11 treatment combinations comprised on pearl millet pure in uniform row at 45 cm and pearl millet in paired row at 30 cm with interspace of 60 cm in between two pairs. Pearl millet at uniform and paired rows was combined with legumes viz., cowpea, clusterbean and rice bean. In case of uniform pearl millet
rows, single alternate row of intercrop at 100% population was maintained for both the crops. In case of paired rows two levels of population (single row with 50% and two rows with 100%) were tried.

The study indicated that the pearl millet in uniform or paired rows had no significant yield difference. The pearl millet yield under all the intercrops was lower than pure crop of pearl millet with both the planting patterns. Almost all the intercropping system more than compensated the drop in yields of pearl millet in association with the intercrops. Amongst the intercrops, cowpea (23.1 q/ha) yielded more than the cluster bean (13.9 q/ha) and rice bean (13.8 q/ha). The highest cowpea (both with 100% population) was significantly superior to remaining treatments. The average productivity of pure pearl millet was 63.3 q/ha, whereas pearl millet + cowpea yielded 71.2 q/ha. The yield increase with intercrops varied from 5.7 to 12.5%.

4.2.1: Studies on bacterial mediated N$_2$–fixation for increased productivity in pasture species.

(M. R. Pahwa)

1. Nodulation growth and forage yield of *Stylosanthes hamata* as influenced by different densities of *Rhizobium*.

In a pot culture experiment seed inoculation with different densities as *Rhizobium* (0, 3.5×10$^2$, 3.5×10$^4$, 3.5×10$^6$ and 3.5×10$^8$ cells/ml inoculum) was tested in CRD with four replications. Pure culture suspension containing 3.5×10$^8$ cells/ml inoculum was found to be the optimum for seed application, as it stimulated nodulation (58/plant) and improved green (14.5 g/plant) and dry matter (3.1 g/plant) accumulation.

2. Efficiency of *Rhizobium* in relation to some plant nutrients (S and Zn) in pasture legumes.

Some of plant nutrients play a vital role in improving the effectiveness of symbiotic N$_2$–fixation. Separate pot culture studies were initiated using red soil (pH=8.20) on three pasture legumes (*Centrosem pubescens*, *Desmodium tortosum* and *Stylosanthes humilis*), so as to know their optimal requirement for Zn and S under inoculated conditions. The data revealed the following results:

(i) ZnSO$_4$ at 20 kg/ha interacted significantly with *Rhizobium* in producing the maxi-
mum number of nodules (14/plant) and root length (20.3 cm) as well as in increasing the forage yield of *C. pubescens*.

(ii) Fertilization with sulphur @ 10 kg/ha was found to increase the efficacy of the inoculum from 38 to 50.5% in case of *D. tortusum*.

(iii) The addition of 10 kg S/ha in conjunction with *Rhizobium* gave stimulatory effect on nodulation (53/plant) root length as well as higher forage yield of *S. humilis*.

The above studies suggest the essentiality of these plant nutrients in improving the efficacy of pasture legume *Rhizobium* symbiotic system.

3. Response of some grasses to *Azotobacter*/*Azospirillum*  

(a) In a pot study, seedling inoculation of four grass species (napier–bajra hybrid–3), *Setaria sphacelata*, guinea grass and *Cenchrus setigerus* with *Azotobacter* was tested with a view to examine its effect on forage productivity. The uninoculated content was kept as a check treatment. Seedlings were inoculated with pure culture suspension of *Azotobacter* (initial count–$5.9 \times 10^4$ cells/ml). Green and dry matter forage yields were significantly increased in two cuttings of *Setaria*, Guinea and *Cenchrus setigerus* due to inoculation. The contribution by *Azotobacter* in case of *Setaria* produced significantly highest total forage yield.

(b) The microplot experiment consisting of three grass species (*Cenchrus ciliaris*, *C. setigerus* and *Dichanthium annulatum*) and two levels of N (0 and 30 kg/ha) with and without seedling inoculation with *A. brasilense*. Significant improvement in green and dry matter yields of all the three grass species was noticed due to seedling inoculation with *Azospirillum brasilense* and the level of increase ranged from 22 to 31.5%. The highest forage yield of *C. setigerus* was produced by the combined treatment of 30 kg N/ha + inoculation which recorded an increase of 38% over uninoculated 30 kg N/ha.

2.5.01 Glimpses of Grazing in India

(R. K. Tyagi)

Under the gwari system of grazing, the cattle from p*ains* are being sent during rainy season to certain selected areas of forest pasture lands which generally occupy plateau and
hilly areas. The system is prevalent only in the forest-grazing lands of Saugar, Damoh, Panna and Chhatarpur districts spread over the Vindhyan ranges and adjoining plateau areas. The dominant species of grasses of this region are Kaila (*Dicanthium annulatum*), Mushia (*Iseilema laxum*), Lampa (*Heteropogon contortus*) and Gunaria (*Themeda quadrivalvis*). Kaila and Mushia generally grow in black soil, while Lampa prefers red and yellow soils. Lampa and Gunaria grasses being nutritively good are sold in the local markets. A large quantity of these grasses are procured from the village community lands and cultivated fields. The poor and middle class farmers graze their animals themselves, while the rich people hire Baredis or Charwahas who take the animals to the gwaris.

The livestock rearing depends upon the availability of grasslands in the neighbourhood. A big farmer keeps about 50-100 cattle heads while the medium 25-30. The livestock raised by the farmers is very unproductive. The daily average milk yield is about 1-2 kg for the cattle and 4-5 kg of the buffalo. The cow-dung is however, more valuable. The animals sent for grazing in the gwaris are cattle (bullocks and calves), buffaloes and goats. The milch animals particularly buffaloes are kept in the village. The goats are kept by Gurdarias (shepherds) and Col and Gond.

After selecting suitable places at the gwaris, the grazier prepares a taparia (temporary hut) for himself and *Konda* or *Bara* for the animals with the help of tree leaves and wood. The animals are taken away for grazing early in the morning and return in the evening. The old persons and children help at the gwaris in respect of milking the animals, taking them for grazing, lifting of cow-dung, preparation of meals, churning of milk etc.

The major problems faced by the graziers are as under:

(i) The grazing lands have been reduced due to the decrease in forest areas as well as afforestation.

(ii) Imposition of several restrictions by the forest departments e.g. grazing fees, charges for making *taparia* and *bara*, ban on the collection of forest produce, declaration of more restricted forest areas and National Park.

(iii) Disappearance of village community lands due to its distribution to land less persons and disposition to the farmers under garden raising programme initiated by the Govt. of Madhya Pradesh.
(iv) Unauthorized possession of waste lands by the rich farmers.

(v) The livestock is very unproductive due to their poor breeds. The cow or buffalo bulls are not provided at the big gwaris centres. Hence non-descript bulls are being used for breeding purpose.

(vi) The castration is being done at a late stage when the male calves become adult. Till their castration they continue to breed.

(vii) The vaccination is not done in required quantity and at proper time due to lack of funds and medicines with the dispensaries.

(viii) The dacoits harass the graziers by taking forcible their animals and households like food-grains, ghee, milk, etc.

The field study of gwaris reveals that their number is reducing every year. It is mainly because of the above mentioned reasons which require immediate attention. The major steps to be taken are the management and improvement of grasslands and introduction of suitable grazing systems. The latest technology of grass harvesting and its conservation should reach to the farmers of this area. Steps should also be taken to improve the livestock wealth of this region. Since the animals brought from other parts do not thrive well in this area, local breeds should be improved.

2.5.2. Grassland and Fodder Atlas of Bundelkhand.

(R. K. Tyagi)

The studies on magnitude of change in net irrigated area in Bundelkhand indicated that it had increased from 5.18 lakh ha in 1970-71 to 6.37 lakh ha in 1981-82 registering an increasing of 22.70%.

The change in land use pattern during some period revealed the following:

Area under forest

The area under forest has increased from 6.26 lakh ha in 1970-71 to 11.03 lakh ha in 1981-82 i.e. 76% increase. The forest area increased in 7 of the 11 districts of Bundelkhand.
The percentage increase varies from 24.44 in Jalaun to 30.47 in Damoh district. It is worth mentioning that the forest area has increased in districts of M. P. part.

Area under waste land

The area under waste land comprising pastures and miscellaneous tree crops and grooves has decreased from 12.64 lakh ha in 1970–71 to 9.65 lakh ha in 1981–82 i.e. 23.6 percent decrease. The reduction in the area is worth mentioning in all the 5 districts of U. P. part. The waste land has increased in the districts of Panna and Damoh of M. P.

Area not available for cultivation

The area under non-agricultural use and barren lands has also reduced from 9.25 lakh ha in 1970–71 to 8.16 lakh ha in 1981–82. It is found to decrease in 8 of the 11 districts. However, districts Chhatarpur, Jhansi and Jalaun recorded an increase in this category of land.

Area under cultivation

The extent of cultivated area comprising the net area sown in the fallow land has changed from 36.59 lakh ha in 1970–71 to 40.27 lakh ha in 1981–82 i.e. an increase of 10%. Moreover, all the districts have recorded an increase in the area under cultivation during this period. The cultivated area has significantly increased in Tikamgarh (26.29%), Chhatarpur (12.73%) and Jhansi (11.47%) districts. In other districts, it is below 10%.

As regards the impact of irrigation on the cropping pattern the following informations have emerged:

More than 95% of the irrigated area is recorded under food crops. The cereals share the major parts among the food grains and wheat is the dominant irrigated crop throughout the region followed by rice particularly in the districts of Damoh, Panna and Jhansi while in Chhatarpur, Lalitpur, Jalaun and Hamirpur barley is second important crop. The pulses and oil seeds come next to cereals from irrigation point of view. Amongst the pulses, gram is the main irrigated crop. The irrigation is provided mainly to the rabi crops. Ninety percent of the irrigated crops receive single irrigation.

Thus it is evident that the region is devoid of commercial crops which contribute to the economy of the farmers. Limited irrigation facilities compel the farmers to grow few food crops only.

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3.1 Soil fertility and plant nutrition studies under Agroforestry system.

(C. R. Hazra and S. B. Tripathi)

1. Forage yield of different winter crops under tree and open canopy as influenced by P fertilization.

The experiment was conducted with three crops viz., lucerne, pea and barley under open and Albizia lebbek canopy. The trees spaced at 5×5 m had an age of 7 years and height 7—8 m. The crops were grown with varying levels of P (0, 13, 26 and 39 kg P/ha). All the crops responded up to 39 kg P/ha under both the canopy situations. Lucerne yielded about 77% of green and 69% of dry forage under-trees as compared to open system. These values for pea were 58% and 62%. The relative green and dry forage yield of barley under trees were 55% and 61%, respectively. The trees allowed about 81% of open PAR to its understory crop surface.

2. Seed yield of different winter crops under tree and open canopy as influenced by P fertilization.

The crops including legumes (gram, lucerne and pea) and cereal (barley) were grown under canopy of Albizia lebbek spaced at 5 m×5 m distance and 7 years old with height of 7–8 m. All these crops were grown with varied P levels (0, 13, 26 and 39 kg P/ha). All the crops responded to 39 kg P/ha under both the canopy systems. Amongst the different crops, the highest relative seed yield was obtained with gram (67%) followed by pea (44%), barley (42%) and lucerne (16%). The tree canopies allowed about 78% of PAR on the understory crop surfaces over the entire growing season. The average open radiation was 1.62×10³/Em²Sec⁻¹.

3. Performance of maize varieties under different tree canopies.

Five winter maize varieties were evaluated for their herbage yield in open and under three different tree canopies viz, Leucaena leucocephala, Acacia nilotica, Hardwickia binata. Leucaena trees were planted at 2m×2m, whereas other trees species were planted at a distance of 5m×5m. The plantations used in the present study were 7 years old with a height
of 6–8 m. The relative photosynthetically active radiation (PAR) under tree were 25% for *Leucaena*, 36% for *Acacia* and 80% for *Hardwickia* treating the open PAR as 100% (1.73 × 10³/ \( \mu \) Em⁻² sec⁻¹).

The highest green and dry forage yields were obtained from varieties Manjri composite. The different maize varieties yielded about 89–99% of green forage and 92–102% of dry forage yield as compared to open system (100%). The yields ranged between 33–61% for green and 31–67% for dry matter under *Acacia* and 23–59% as green and 27–65% dry forage under *Acacia*. On an average, *Hardwickia* gave about 94% green and 99% dry matter yields, whereas the corresponding yields under *Acacia* were 44 and 45% and 31 and 34% under *Leucaena*. Amongst the different maize varieties, genepool was least sensitive to radiation curtailment. Although Manjri composite was found to be high yielder under non shady condition but was most susceptible to radiation curtailment.

3.3.2 Evaluation of nutritional status of forage under agroforestry system.

(Neelam Kewalramani, & C. R. Hazra)

The samples of different crops and their varieties viz., berseem, oat, hybrid napier and guar were collected. The bulk density measurement and chemical analysis of different herbage materials were taken up. It was observed that the CP content in different guar varieties ranged from 18.59 to 24.17 per cent, whereas the crude fibre ranged from 15.78 to 22.68 per cent. The varieties of berseem showed high CP value ranging from 23.9 to 30.1 per cent. The CP content of different varieties of oat ranged from 12 to 18 per cent. Oat variety OL–88 showed the highest CP value of 18.83 per cent.

The samples of hybrid napier were collected at two stages of growth i.e. in July and in October. The data revealed that the bulk density was significantly correlated with CP, CP and OM. There was a positive and significant (\( P < 0.01 \)) correlation between bulk density and crude protein, whereas bulk density was negatively correlated with crude fibre. These observations lead to conclude that as the crude fibre content increase, the bulk density goes down indicating poor nutritive value of the forages. The following regression equation were derived.

1. \[
Y = 1.8748 + 0.0913 X (n=39, r = +0.70, p < 0.01)
\]
where X = crude protein content of the sample (%)
Y = Bulk density (g/1000 ml).

2. \( Y = 36.8525 - 0.0580 \times X \) \( (n=30, r=-0.49, p < 0.01) \)
where \( Y = \) Bulk density (g/1000 ml)
\( X = \) Crude fibre of the plant sample (%)

3. \( Y = 72.45 + 0.0840 \times X \) \( (n=39, r=+0.73, P < 0.01) \)
where \( y = \) Bulk density (g/1000 ml)
\( x = \) Organic matter (%)

3.4.3 Studies on bacterial mediated \( \text{N}_2 \) fixation under agroforestry system of forage production.

(M. R. Pahwa)

1. Efficiency of rhizobial inoculation under phosphorus fertilization.

The present investigation was taken with a view to examine the efficiency of \textit{Leucaena Rhizobium} (\textit{R. loti}) under different levels of phosphorus fertilization (0, 20, 40, 60 and 80 kg \( \text{P}_2\text{O}_5/\text{ha} \) \textit{Leucaena} (Var-k-8) seed treatment with \textit{Rhizobium} mixed strains of TAL-582 + LL-28.2) in combination with phosphate increased the green and dry matter yields over phosphorus alone. The interaction between phosphorus and \textit{Rhizobium} inoculation was significant.

The level of 60 kg \( \text{P}_2\text{O}_5/\text{ha} \) interacted significantly with inoculation in producing 32.7\% & 38\% higher green and dry matter yields over uninoculated 60 kg \( \text{P}_2\text{O}_5/\text{ha} \). The mean percentage increase in green and dry matter production due to inoculation was found to be 19.8\%.

3.5.1 Forage production of grasses under trees in relation to micrometeorological parameters.

(C. R. Hazra)

The field experiment was conducted in alfisols with five treatments viz. \textit{Albizia lebbeck}, \textit{Albizia procera}, \textit{Leucaena leucocephala}, \textit{Acacia nilotica} and open grassland in R. B. D. replicated four times.
The experimental results indicated that the radiation infiltration through trees was of the order of 60–64% as compared to open grassland. The relative humidity under tree canopies ranged between 82 to 92% against 72% in open. The ambient air temperature under trees varied between 32.8 °C to 34.2°C against 36°C in open. The leaf temperature for grasses varied between 28.0–29.5°C under trees whereas it was 32.9°C in open grassland. The dry forage yield under trees varied from 76–95% of open plots. The grass yield were of the following order open (69.8 q/ha) > Albizia lebbek (66.6 q/ha) > Leucaena leucocephala (62.3 q/ha) > Albizia procera (58.9 q/ha) > Acacia nilotica (52.8 q/ha).

3.5.2 Influence of tree species on radiation infiltration and forage yield of grasses.

(C. R. Hazra)

The study was conducted in red soil (alfisols) with 8 tree species with open grassland as control in R. B. D, replicated three times. The results indicated that the productivity of grasses in association with trees were less than the open grasslands by 3–31% depending upon the tree species. The trees allowed 58–83% of normal PAR (open lands) to the grass canopies in association. Amongst the tree species the order of radiation infiltration in comparison to open lands were of the order of Hardwickia binata (83%) > Eucalyptus species (78%) > Dichrostachys nutans (74%) > Acacia tortilis (72%) > Albizia procera (64%). However the forage productivity was of the order of Albizia lebbek (97%) > Hardwickia binata (91%) > Leucaena leucocephala (88%) > Acacia tortilis (81%) > Albizia procera (79%) > Acacia nilotica (77%) > Eucalyptus species (69%). Thus the productivity of grasses are strongly dependent on the tree association and less dependent on radiation availability.

3.5.3 Forage productivity of pasture grasses and legumes with and without tree association in relation to N application.

(C. R. Hazra)

The field experiment was conducted with Cenchrus ciliaris and different pasture legumes as intercrops under silvipastoral and open system with varying nitrogen levels. The treatment included two tree situation in main plots and the combinations of seven crops and
three N levels in sub-plot in split plot design. *Hardwickia binata* planted at 5m x 5m spacing in the year 1978 with about 7-8 m height was taken as tree canopy. The cropping systems were *Cenchrus ciliaris*, *Siratro Clitoria ternatia* and *Stylosanthes hamata* as pure crops and *Cenchrus* combined with each of the pasture legumes as intercrops. The N levels to each crop situations were 0, 20, and 40 kg N/ha.

The experimental results indicated that the intercropping of grasses and legumes yielded always higher than the pure yield of grass or legumes. *Cenchrus* in pure stand yielded about 60–70% of the yields obtained with intercropping. The yields under open were always more than under trees. However, pure stand of *Cenchrus* was not affected by tree canopy. The effect of N was observed to be linear up to 40 kg N/ha in case pure *Cenchrus*, whereas legumes and intercrops responded to 20 kg N/ha. The LER values for the mixed stands were 1.38 to 1.77. On an average the tree allowed about 72% of PAR to that of open canopy situation.

3.5.4 Performance of winter maize varieties for forages at different sowing dates under calcareous soil.

(C. R. Hazra and I. Y. L. N. Murthy)

Six winter maize varieties were tested at three different sowing dates viz., mid December, end December and mid-January. The experiment was taken up in factorial R. B. D. with 18 treatment combinations. The yield data indicated that highest green and dry forage yields were obtained with early sowing in mid December. The yields decreased with delay in sowings. The sowing at the end of December and mid-January gave 70 and 56% yields that obtained with sowing in mid December. Amongst the different varieties, the highest dry forage yield was obtained from Manjri composite (26.7 q/ha) followed by Manjri (24.8 q/ha), Jaunpuri (23.6 q/ha) and African tall (22.0 q/ha). The other two varieties gave only 13.2–16.3 q/ha of dry forage.

3.5.6 Grain yield of winter maize varieties as influenced by sowing dates under calcareous soil.

(C. R. Hazra and I. Y. L. N. Murthy)

Six winter maize varieties were tested in a calcareous soil for their grain yield productivity. The varieties were tested at 3 different sowing dates to find out the suitable sowing
period for this crop. The treatment combinations included 6 varieties and 3 sowing dates and were tested in factorial R. B. D. Amongst the different sowing dates, mid December sowing gave the highest yield of 12.4 q/ha of grain followed by 10.1 q/ha with end December and 8.2 q/ha with mid January sowings. Thus the delayed sowing by one month from mid December gave only 2/3 yield. Amongst the different varieties tested, Manjri composite gave the highest grain yield of 11.5 q/ha followed by African tall (10.9 q/ha).

4.5.7 Effect of P and Mo on forage yield of cowpea in calcareous soil.

(S. B. Tripathi and C. R. Hazra)

The availability of P and Mo is very low in calcareous soil and the legume yields are low in such soils. Four important cowpea varieties were tested in calcareous soil with three P levels (0, 13 and 26 kg P/ha) in combination with two levels of Mo on herbage yields of cowpea. The main effects of P and Mo indicated that the highest green (362.5 q/ha) and dry forage (44.5 q/ha) yields were obtained with 26 kg P and 1 kg MoO₃/ha. Mo application improved herbage yield by 13%. Amongst the different varieties, UPC-9805, UPC-9030 and UPC-5286 had almost similar yield levels (34.3-36.7 q DM/ha).

3.5.8 Effect of P to different forage sequential croppings under calcareous soil.

(S. B. Tripathi & C. R. Hazra)

A field experiment was conducted with crop rotations involving different perennial and annual crops for finding out the effect of P on the crop sequence under calcareous soil. The crop sequences viz. napier-cat, napier-cowpea-oat, bajra-oat, bajra-cowpea-oat, cowpea-oat were evaluated at P levels of 0, 40 and 80 kg P₂O₅/ha. The study indicated that napier-cowpea gave the highest forage yield during kharif under napier-cowpea-oat cropping system. The highest forage yield was observed at 80 kg P₂O₅/ha.

3.5.9 Herbage yield of lucerne as influenced by soil management and P application in calcareous soil.

(C. R. Hazra and S. B. Tripathi)

The experiment was conducted in red sandy loam soil with a view to find out suitable soil management practices and P requirement of lucerne crop. The soil contained about 5% Ca CO₃. The treatment combinations included the combination of 3 soil management practices and 4 levels of P in factorial R. B. D.
The dry and green forage yields of lucerne were greatly improved up to the level of 52.5 kg P/ha with different soil management practices. The response in terms of dry forage yield was to the tune of 67, 64 and 61 kg per kg of P applied at 17.5, 35.0 and 52.5 kg P/ha, respectively. Amongst the soil management treatments, the puddling of soil at sowing with broadcast P had the highest effect on yield (62.8 q/ha of dry forage) followed by dry seeding and raking with broadcast P (55.5 q/ha). The average response to each kg of applied P was 74.66 and 60 kg dry matter/ha with puddling, dry seeding and normal tillage, respectively. The corresponding relative P uptake values were 113, 108 and 100. The puddled plots maintained higher soil temperature but lower canopy temperature at the beginning.

3.5.10 Forage production of cowpea varieties as influenced by P application in different acid soil.

(S. B. Tripathi and C. R. Hazra)

An experiment was conducted in pots with three cowpea varieties viz. UPC-5285, UPC-9805 and UFC-8988 with three levels of P (0, 40 and 80 kg P₂O₅/ha) in four soils viz., Jorhat (pH 5.8), Palampur (pH 6.2), Mannavanore (pH 5.1) and Jhansi (pH 7.1). The study indicated that cowpea varieties significantly responded to 80 kg P₂O₅/ha. The cowpea variety UPC-9805 was highest yielder and maintained significant superiority over other varieties. Amongst the soils, the highest yield was obtained in neutral soil of Jhansi (33.5 g/pot) followed by acid soil of Palampur (30.1 g/pot), Jorhat (28.4 g/pot) and manuvanare (25.4 g/pot).

3.5.11 Forage production of winter maize varieties as influenced by P application in different acid soil.

(S. B. Tripathi and C. R. Hazra)

Five winter maize varieties were tested in four different soils at 2 levels of P in pots. The winter maize varieties were Genepool, Manjri, Manjri composite, Jaunpuri and Tinpakia. Two P levels were 0 and 80 kg P₂O₅/ha. The soils were from Palampur (pH 6.2), Jorhat (pH 5.8), Mannavanore (pH 5.1), and Jhansi (pH 7.1). The data indicated that the productivity of soils was directly related to soil pH, the yield in neutral soil of Jhansi was 42.0 g/pot, whereas the yields in mild acid soil of Palampur was 34.0 g, moderate acid soil of Jorhat 27.0 g and highly acid soil of Mannavanore 25.4 g/pot. The uptake of P followed the pattern of yields. The yield of maize varieties was significantly improved with 80 kg P₂O₅/ha. The increase in yield was 29 per cent and in P uptake 68 per cent over control treatment. Amongst the five varieties, the highest dry forage was recorded with Manjri composite (36.6 q/ha). Treating the yield of Manjri composite as 100, the relative yields of 91, 85, 84 and 79 per cent were obtained with Manjri, Jaunpuri, Tinpakia and genepool respectively.

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DIVISION OF GRASSLAND MANAGEMENT

GM-1 ESTABLISHMENT AND MANAGEMENT OF RESEEDED PASTURES FOR THEIR SUSTAINED PRODUCTIVITY ON MARGINAL AND SUB-MARGINAL LANDS.

1.2. Studies on the establishment and management of Stylosanthes, Cenchrus and Dichanthium based pastures for their sustained productivity.

(P. Rai)

1. Effect of different depths of sowing on the establishment of different species of grasses and legumes.

Studies on the effect of 7 depths (0, 0.4, 0.8, 1.2, 1.6, 2.0 and 2.4 cm) of sowing on the establishment of 5 species of Stylosanthes (S. guianensis, S. hamata, S. scabra, S. viscosa and S. humilis) and 4 grasses (Dichanthium annulatum, Cenchrus ciliaris, Cenchrus setigerus and Cenchrus hybrid) showed that in S. guianensis maximum establishment percentage (42.3%) was recorded at 1.2 cm depth followed by 0.8 cm (38.7%). In case of S. hamata, the maximum (20.3%) was obtained at 0.4 and 0.8 cm depth. In S. scabra, the maximum establishment was recorded at 1.2 cm depth (32.3%) followed by 0.8 cm (30.2%). In case of S. viscosa, the highest establishment of 54.0 percent was recorded at 0.8 cm depth followed by 53.3 per cent at 1.2 cm and 41.7 per cent at 1.6 cm. None of the seeds germinated at 2.4 cm depth. In S. humilis, the maximum establishment was recorded when sowing was done at 0.8 cm (41.7%) followed by 1.2 cm (34.7%).

In grasses the maximum establishment was obtained at the sowing depth of 0.8 cm in case of C. ciliaris, C. setigerus and D. annulatum followed by 0.4 cm. In cases of Cenchrus hybrid, the highest establishment was recorded at 0.4 cm depth followed by 0.8 cm.
2. Effect of different seed rates and methods of sowing on the establishment of *Cenchrus setigerus* and *Cenchrus* hybrid.

The study on effect of 8 seed rates (2, 4, 6, 8, 10, 12, 14 and 16 kg/ha) and 2 methods of sowing (broadcasting and line sowing) was conducted to know the optimum seed rate and suitable methods of sowing on the establishment of *Cenchrus* hybrid and *C. setigerus*.

The different methods of sowing resulted in the differences in plant population which was significant in both the grasses. The maximum plant population of 96,667 and 105,417 plants/ha were recorded with *C. setigerus* and *Cenchrus* hybrid, respectively when sowing was done by broad-cast method.

The differences in plant population due to different seed rates were also found significant in both the grasses. The maximum plant population of 1,36,667 and 1,38,000 plants/ha were recorded with *C. setigerus* and *Cenchrus* hybrid, respectively at 16 kg/ha seed rate. However, the differences in plant population recorded from 8 to 16 kg/ha were not significant in case of *Cenchrus* hybrid and 12 to 16 kg/ha in case of *C. setigerus*.

The different seed rates and sowing methods resulted in significant variation in green and dry matter yields. The maximum yield was recorded at sowing rate of 12 kg/ha in case of *C. setigerus* and 16 kg/ha in *Cenchrus* hybrid. Forage yield obtained due to broad-cast method of sowing gave 64.3 and 39.0 percent higher yield in *Cenchrus setigerus* and *Cenchrus* hybrid, respectively over line sowing.

3. Effect of different materials and frequency of weeding on the establishment and production of *Cenchrus setigerus* and *Cenchrus* hybrid.

The study with 3 planting materials (seeds, seedlings and rooted slips) and 3 frequencies of weeding (0, 1 and 2 weeding during rainy season) on the establishment and production of *C. setigerus* and *Cenchrus* hybrid showed significant difference due to different materials in both the grasses. In *Cenchrus setigerus*, the maximum plant population of 1, 55,556 plant/ha was recorded when planting was done with seedlings which was significantly higher than others. In case of *Cenchrus* hybrid, the maximum plant population (1, 48, 889 plants/ha) was recorded with rooted slips. The plant population recorded with rooted slips and seedlings did not differ significantly. There was no significant differences due to different weeding treatments in both the grasses. However, the maximum
plant population (1, 21, 111 plants/ha) was recorded when two weedings were done in case of *C. setigerus*, and one weeding in case of *Cenchrus* hybrid (1,30,000/ha).

The plant height and tussock diameter showed significant difference due to different planting materials in both the grasses. However, differences in plant height and tussock diameter of seedlings and rooted slips were non significant. The maximum plant height of 121.1 and 123.3 cm was recorded in *C. setigerus* and *Cenchrus* hybrid, respectively, when planting was done with rooted slips. The tiller production showed significant difference due to different weedings. The maximum plant height, number of tillers per plant and tussock diameter were recorded when two weedings were done in both the cases.

The differences in dry matter yield were significantly affected due to the different planting materials in both the grasses. In *C. setigerus*, the maximum yield (35.3 q/ha) was obtained when planting was with seedlings, while in *Cenchrus* hybrid, it was with rooted slips (46.4 q/ha). The forage yield was significantly affected due to weeding in both the grasses and the maximum was produced with two weedings in both grasses. However, the yield differences with one or two weedings were statistically non significant.

4. Effect of management practices on the productivity of sown pastures.

Several experiments were initiated on range grasses viz., *Dichanthium annulatum*, *Cenchrus ciliaris*, *Cenchrus setigerus* and *Cenchrus* hybrid and legume, *Stylosanthes hamata* in pure stand as well as in mixtures to know the suitable management practices and stability of pasture species established in 1984. Four treatments such as grass alone (control), grass + interculture, grass + 60 kg N/ha + 30 kg P₂O₅/ha and grass + interculture + 60 kg N/ha + 30 kg P₂O₅/ha in case of pure stand of grass while in mixtures, grass + legume (control), grass + legume + interculture, grass + legume + 30 kg N/ha + 60 kg P₂O₅/ha and grass + legume + interculture + 30 kg N/ha + 60 kg P₂O₅/ha were employed. In case of pure stand of legume, the four treatments such as control, 60 kg P₂O₅/ha, 20 kg S/ha and 60 kg P₂O₅/ha + 20 kg S/ha were used. The treatments were replicated six times in all the pure and mixed stands.

Pure stand of grasses : The green and dry forage yield significantly increased with the application of fertilizers as well as interculture + fertilizers as compared to grass alone (control) and grass + interculture in all the grasses (table 16). Due to interculture, the forage yield increased in all the grasses compared to control but it was statistically non-significant.
In *Dicanthium annulatum*, the maximum green (167.8 q/ha) and dry (49.3 q/ha) forage yields were obtained with interculture-application of 60 kg N + 30 kg P₂O₅/ha followed by application of 60 kg N + 30 kg P₂O₅/ha. However, there was no significant difference in forage yield obtained with interculture-fertilizer and only fertilizer application.

Table 16: Green and dry forage yield (q/ha) in different range grasses grown in pure stand.

<table>
<thead>
<tr>
<th>Treatments</th>
<th><em>D. annulatum</em></th>
<th><em>C. setigerus</em></th>
<th><em>C. ciliaris</em></th>
<th><em>Cenchrus hybrid</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Dry</td>
<td>Green</td>
<td>Dry</td>
</tr>
<tr>
<td>Grass alone (G)</td>
<td>117.8</td>
<td>33.8</td>
<td>187.7</td>
<td>46.2</td>
</tr>
<tr>
<td>G + interculture</td>
<td>122.9</td>
<td>36.6</td>
<td>200.7</td>
<td>50.0</td>
</tr>
<tr>
<td>G + 60 kg N + 30 kg P₂O₅/ha</td>
<td>148.8</td>
<td>47.1</td>
<td>261.2</td>
<td>66.3</td>
</tr>
<tr>
<td>G + interculture + 60 kg N + 30 kg P₂O₅/ha</td>
<td>167.8</td>
<td>49.3</td>
<td>265.9</td>
<td>65.7</td>
</tr>
<tr>
<td>SE m±</td>
<td>8.8</td>
<td>2.6</td>
<td>15.9</td>
<td>4.0</td>
</tr>
<tr>
<td>CD at 5%</td>
<td>26.5</td>
<td>7.8</td>
<td>47.9</td>
<td>12.0</td>
</tr>
<tr>
<td>Mean</td>
<td>139.9</td>
<td>41.7</td>
<td>228.9</td>
<td>57.1</td>
</tr>
</tbody>
</table>

In case of *C. setigerus*, the maximum green forage yield (265.9 q/ha) was obtained with interculture + 60 kg N + 30 kg P₂O₅/ha while the maximum dry matter yield (66.3 q/ha) was recorded with application of 60 kg N + 30 kg P₂O₅/ha followed by interculture + 60 kg N + 30 kg P₂O₅/ha (65.7 q/ha).

In *C. ciliaris*, the maximum green (296.2 q/ha) and dry (73.9 q/ha) forage yields were obtained with application of 60 kg N + 30 kg P₂O₅/ha followed by interculture + 60 kg N + 30 kg P₂O₅/ha (286.3 q/ha green and 71.2 q/ha dry).

In case of *Cenchrus hybrid*, the maximum green forage production (295.9 q/ha) and dry matter yield (81.1 q/ha) were obtained with interculture + 60 kg N + 30 kg P₂O₅/ha.
Among the four grasses, the mean maximum green forage yield was recorded with *C. ciliaris* (247.8 q/ha) followed by *Cenchrus* hybrid (241.3 q/ha), while the dry matter yield was maximum (64.9 q/ha) in case of *Cenchrus* hybrid followed by *C. ciliaris*.

Pure stand of legume: The total green and dry forage yields obtained in three cuttings did not show significant differences due to application of phosphorus and sulphur. However, the maximum green (187.1 q/ha) and dry (53.7 q/ha) forage yields were recorded with application of 60 kg $P_2O_5$/ha+20 kg S/ha followed by the application of 60 kg $P_2O_5$/ha (177.0 q/ha green and 49.2 q/ha dry).

Grass-legume mixtures: The total production of grass+legume mixtures showed that the total green and dry forage yield differed significantly with different management practices. In the mixture of *D. annulatum* + *S. hamata*, the maximum green forage production of 165.6 q/ha (126.3 q/ha from grass 39.1 q/ha from legume) and dry matter yield of 58.3 q/ha (45.7 q/ha from grass+12.6 q/ha from legume) was obtained with interculture+30 kg N/ha+60 kg $P_2O_5$/ha.

In case of *C. setigerus* + *S. hamata*, the maximum green forage production of 239.9 q/ha (151.9 q/ha from grass+88.0 q/ha legume) was obtained with interculture+30 kg N+60 kg $P_2O_5$/ha while, the maximum dry matter yield of 73.0 q/ha (42.2 q/ha from grass+30.8 q/ha from legume) was recorded with the application of 30 kg N+60 kg $P_2O_5$/ha.

In the mixture of *C. ciliaris* + *S. hamata*, the maximum green forage yield of 202.9 q/ha (141.2 q/ha from grass+61.7 q/ha from legume) was recorded with interculture+30 kg N+60 kg $P_2O_5$/ha while, the maximum dry matter yield of 79.3 q/ha (59.3 q/ha from grass+20.0 q/ha from legume) was noted with application of 30 kg N+60 kg $P_2O_5$/ha.

In *Cenchrus* hybrid, the maximum green forage production of 215.5 q/ha (152.1 q/ha from grass+63.4 q/ha from legume) and dry matter yield of 76.1 q/ha (56.1 q/ha from grass+20.0 q/ha from legume) were obtained with application of 30 kg N+60 kg $P_2O_5$/ha followed by interculture+30 kg N+60 kg $P_2O_5$/ha.

Among the four mixtures, the mean maximum green forage yield 198.8 q/ha (117.6 q/ha from grass+81.2 q/ha from legume) was obtained with *C. setigerus* + *S. hamata* followed by *Cenchrus* hybrid + *S. hamata* (130.4 q/ha from grass+60.5 q/ha from legume=190.9 q/ha) and *C. ciliaris* + *S. hamata* (178.4 q/ha) while the highest dry matter yield of 69.1 q/ha

(113)
was recorded with *C. ciliaris* + *S. hamata* followed by *Cenchrus* hybrid + *S. hamata* (67.2 q/ha) and *C. setigerus* + *S. hamata* (62.3 q/ha). The minimum green and dry forage yields were obtained in the mixture of *D. annulatum* + *S. hamata*.

5. Effect of different levels of nitrogen on the productivity of pure and mixed stand of *Cenchrus* hybrid.

The experiment was continued for the third year to know the effect of 3 levels of nitrogen (0, 30 and 60 kg N/ha) on the productivity of pure stand of *Cenchrus* hybrid and its mixed stand with *S. hamata*. Dry matter yield significantly increased with application of nitrogen in case of pure stand while the significant differences were not observed among the mixed stand (table—17).

Table 17 Effect of different levels of nitrogen on the growth attributes and dry matter yield (q/ha), in *Cenchrus* hybrid grown in pure and mixed stand.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Growth attributes</th>
<th>Dry matter yield</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>plant height (cm)</td>
<td>No. of tillers/ plant</td>
<td>Grass</td>
</tr>
<tr>
<td>Grass alone (control)</td>
<td>150.5</td>
<td>34.7</td>
<td>103.9</td>
</tr>
<tr>
<td>G+30 kg N/ha</td>
<td>160.5</td>
<td>44.0</td>
<td>122.5</td>
</tr>
<tr>
<td>G+60 kg N/ha</td>
<td>160.7</td>
<td>41.5</td>
<td>130.2</td>
</tr>
<tr>
<td>G+S. hamata (L)</td>
<td>154.6</td>
<td>40.7</td>
<td>88.4</td>
</tr>
<tr>
<td>G+L+30 kg N/ha</td>
<td>156.7</td>
<td>43.7</td>
<td>96.4</td>
</tr>
<tr>
<td>G+L+60 kg N/ha</td>
<td>159.5</td>
<td>44.5</td>
<td>103.3</td>
</tr>
<tr>
<td>SE (m) ±</td>
<td>4.1</td>
<td>4.0</td>
<td>—</td>
</tr>
<tr>
<td>C. D. at 5%</td>
<td>N.S.</td>
<td>N.S.</td>
<td>—</td>
</tr>
<tr>
<td>Mean</td>
<td>157.0</td>
<td>41.5</td>
<td>—</td>
</tr>
</tbody>
</table>

( 114 )
The maximum dry matter yield of 130.2 q/ha was recorded with the application of 60 kg N/ha followed by 30 kg N/ha (122.5 q/ha) when growth in pure stand. However, the dry matter yield obtained with 30 and 60 kg N/ha did not differ significantly. The minimum dry matter yield of 100.4 q/ha (88.4 q/ha from grass + 12.0 q/ha from legume) was recorded with mixture of Cenchrus + S. hamata. Data on vigour attributes showed that there were no significant differences in plant height and tiller production due to application of nitrogen. However, the highest plant length (160.7 cm) and number of tillers per plant (44.5) were recorded with application of 60 kg N/ha in pure and mixed stand, respectively.


Studies were continued for the second year to compare the performance of mandya sheep grazing on the pure stand of D. annulatum and mixed stand of D. annulatum + Stylosanthes hamata. Data on body weights of sheep showed that the animals grazed in pure pasture of D. annulatum maintained their body weight upto 18-11-85 and the maximum gain was recorded 3.6 g/sheep/day. In case of mixed pasture of D. annulatum + S. hamata the maximum body weight gain was 9.0 g/sheep/day and the animals maintained their body weight upto 2-12-85.

The results revealed that the animals grazed on mixed pasture maintained their body weight for longer duration and gained higher body weight as compared to those in pure pasture of Dichanthium. The better performance of sheep on mixed pasture is due to better quality of herbage available in mixed stand, since the forage production in both the pastures were more or less same. Further, data recorded on plant population of D. annulatum and S. hamata revealed that the plant population of Dichanthium was same as in previous year, while in case of S. hamata the plant population was lower (110,000 plant/ha) as compared to that of last year (2,10,000 plants/ha), thus indicating its decrease due to grazing.

1.5 Studies on range grasses as influenced by cutting management-cum-fertilizers under rainfed conditions Heteropogon contortus.

(K. C. Kanodia, K. P. Niranjan and S. S. Parihar)

Studies with three cutting intervals (20, 40 and 60 days) vis-a-vis four doses of N-fertilizer (0, 30, 60 and 90 kg N/ha) replicated thrice in randomised block design in established Heteropogon contortus pasture were repeated during second year.
Data on dry matter yield showed significant difference due to different cutting intervals (Table 18). But the differences in forage yield among the 20 and 40 days cutting intervals were non-significant. The highest dry matter production, was obtained (66.0 q/ha), at 60 days cutting interval, followed by 40 days (43.8 q/ha). The forage production significantly differed due to different levels of nitrogen. The maximum dry matter yield (65.4 q/ha) was obtained with application of 90 kg N/ha, followed by 60 kg N/ha (57.7 q/ha).

As regards to interaction, the maximum forage yield of 83.3 q/ha was obtained with 50 days cutting interval x 90 kg N/ha, followed by harvesting at 60 days interval x 60 kg N/ha (78.0 q/ha). The minimum dry matter (28.0 q/ha) was recorded when harvesting was done at 20 days interval without application of nitrogen. Improved productivity was recorded in comparison to that of last year.

Table 18 Effect of cutting interval and manuring on grassland productivity.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Production (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Interval (Days)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Manuring (N kg/ha)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.6. Evaluation of productivity of Chrysopogen pastures with and without legumes.
(K. P. Niranjan and K. C. Kanodia)

1  Chrysopogen fulvus cv. Chandigarh + Sesbania

This was the third year of experimentation. The treatments comprised of pure
stand of *Chrysopogon fulus* cv. Chandigarh, fertilized with 0, 45 and 90 kg N/ha. *Sesbania sesban*, a leguminous, shrub was intercropped with the grass to test its efficacy in increasing the yield of herbage. The fertilizer treatments in the mixed stand consisted of all combinations of two levels of nitrogen (0 and 45 kg/ha). The experiment was conducted in R. B. D. with three replicates.

Results showed that the maximum mixed dry forage yield 34.52 q/ha (32.41 grass + 2.11 legume) was obtained from *Chrysopogon fulus* intercropped with *Sesbania* and fertilized with 45 kg N + 30 kg P₂O₅/ha, followed by mixed stand along with the application of 45 kg N + 60 kg P₂O₅/ha (33.80 q/ha) 31.33 grass + 2.47 legume. Minimum dry forage yield was obtained (23.16 q/ha) in pure stand of grass without any fertilizer dose.

2. *Chrysopogon* cv. *mhow* + *Stylosanthes scabra*.

The treatments was initiated during the year in established stand on the growth. The treatments comprised of pure stand of *Chrysopogon fulus* cv. *mhow* fertilized with 0, 45 and 90 kg N/ha. *Stylosanthes scabra* (40289) a forage legume was intercropped with the grass to test its efficiency in increasing the yield of herbage. The fertilizer treatments in the mixed stand consisted of all combinations of two levels of nitrogen (0 and 45 kg/ha) and three levels of phosphate (0, 30 and 60 kg P₂O₅/ha). The experiment was conducted in randomised block design with three replications.

Results showed that the maximum mixed dry forage yield 81.93 q/ha (53.69 grass + 28.24 legume) was obtained from *Chrysopogon fulus* intercropped with *Stylosanthes* and fertilized with 45 kg N + 60 kg P₂O₅/ha followed by 73.52 q/ha mixed stand along with the application 45 kg N + 30 P₂O₅/ha. Minimum dry forage yield 31.75 q/ha was obtained with the pure stand of grass without any fertilizer application.

1.7. Studies on competitive and adaptive features of sown grassland ecosystem.


1. Evaluation and management studies of forage species in sown grassland ecosystem.
grown in monocultures and in mixture of 1:1 proportion. One each of the grass monoculture received 60 kg N/ha fertilisation while one each of grass/legume mixture received 60 kg P\textsubscript{2}O\textsubscript{5}/ha fertilisation so as to compare the nitrogen economy through growing of grass/legume mixtures.

Out of various combinations tried, grasses *Setaria sphacelata*, *Brachiaria brizantha* and *Panicum coloratum* with legume *Stylosanthes hamata* cv. Verano under 60 kg P\textsubscript{2}O\textsubscript{5}/ha fertilization yielded highest dry matter production as compared to other treatments. Yields were lowest in untreated (control) grass plots in the above species. In case of *Panicum maximum* cv. Gatton highest dry matter yield was recorded in plots where the grass was grown along with *S. kamata*. Growing of *Stylosanthes hamata* with the above said grasses under 60 kg P\textsubscript{2}O\textsubscript{5}/ha fertilizer recorded highest dry matter production as under:

1. *Brachiaria brizantha* + *S. hamata*—67.0 q/ha
2. *Panicum coloratum* + *S. hamata*—69.91 q/ha (3)
3. *Setaria sphacelata* + *S. hamata*—91.42 q/ha.

Dry matter yield in the plots of above grasses, legume monoculture and nitrogen fertilised grasses were intermediate. In case of grass *Panicum maximum* cv. Gatton, the highest dry matter yield of 81.9 q/ha was recorded in grass- legume mixture plots followed by phosphate fertilised grass/legume mixture.

In case of *Bothriochloa intermedia* the highest dry matter yield was recorded in pure plots of legume viz (1) Caribbean stylo—24 q/ha and Siratro—31 q/ha. In *Panicum antidotale* the highest dry matter yields of 39.2 q/ha and 41.6 q/ha were obtained in nitrogen fertilised grass as compared to grass + legume mixtures with or without fertilisation.

In another experiment thirteen ecological races of *Cenchrus ciliaris* grown along with *Stylosanthes hamata* cv. Verano in 1:1 proportion showed differential performance in dry matter yield. Among *C. ciliaris* races grown along with Caribbean Stylo, total dry herbage yield was recorded maximum in races (1) 3108—61.11 q/ha; (2) 3123—60.89 q/ha; (3) Pusa giant anjan—58.56 q/ha; (4) Jodhpur local—57.28 q/ha. It was lowest in No. 262 registering an yield of 24.35 q/ha only.

The most adequate mixtures adjudged were (1) Jodhpur local (2) 59–1 and 3108
Further, slight deterioration was observed in the stand of *Stylosanthes hamata*, as the legume needs reseeding every 3rd or 4th year, because of its biennial nature.

Comparative growth performance of various grasses and legumes were studied during June 1985. The seedlings of grasses and legumes raised during June 1985 were transplanted in $3 \times 2.5$ m$^2$ plots in 3 replications to record growth attributes and dry matter production every fortnightly starting from 15th July onwards. The period in which the maximum dry matter was registered in respective species is reported as under:

<table>
<thead>
<tr>
<th>Grass species</th>
<th>Fortnight with maximum yield</th>
<th>Contribution from stem g.</th>
<th>Contribution from leaf g.</th>
<th>Highest yield/fortnight q/ha</th>
<th>L/S ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Sehima nervosum</em></td>
<td>2nd fortnight, November</td>
<td>32.0</td>
<td>17.9</td>
<td>19.94</td>
<td>0.558</td>
</tr>
<tr>
<td>2. <em>Heteropogon contortus</em></td>
<td>1st Fortnight November</td>
<td>53.1</td>
<td>14.3</td>
<td>26.96</td>
<td>0.270</td>
</tr>
<tr>
<td>3. <em>Bothrichloa intermedia</em></td>
<td>1st Fortnight November</td>
<td>39.6</td>
<td>17.1</td>
<td>22.68</td>
<td>0.432</td>
</tr>
<tr>
<td>4. <em>Setaria sphacelata</em></td>
<td>2nd Fortnight, November</td>
<td>13.6</td>
<td>13.5</td>
<td>10.82</td>
<td>0.990</td>
</tr>
<tr>
<td>5. <em>Brachiaria brizantha</em></td>
<td>2nd Fortnight, October</td>
<td>41.7</td>
<td>22.3</td>
<td>25.60</td>
<td>0.534</td>
</tr>
<tr>
<td>6. <em>Paspalum dilatatum</em></td>
<td>2nd Fortnight, October</td>
<td>38.8</td>
<td>42.3</td>
<td>32.40</td>
<td>1.097</td>
</tr>
<tr>
<td>7. <em>Dichanthium annulatum</em></td>
<td>2nd Fortnight, November</td>
<td>32.8</td>
<td>18.1</td>
<td>20.40</td>
<td>0.551</td>
</tr>
<tr>
<td>8. <em>Cenchrus ciliaris</em></td>
<td>2nd Fortnight, November</td>
<td>40.8</td>
<td>21.9</td>
<td>25.06</td>
<td>0.536</td>
</tr>
</tbody>
</table>

(119)
During early stages of growth, leaf portion was much higher than the stem portion. As growth progress, stem portion adds more dry matter to the total herbage production. However, in some of the grasses viz. Paspalum dilatatum the leaf/stem ratio remains more or less equal as compared to others grasses like Heteropogon contortus and Bothriochloa intermedia where the stem ratio becomes comparatively very high. Further Paspalum dilatatum was found to possess a high ratio of leafiness and also higher dry matter yield in the second fortnight of October. Of the four range legumes tried Siratro, Caribbean Stylo and phassy bean recorded maximum production in the 2nd fortnight of October leaf-stem ratio of 0.893, 0.629 and 0.554 respectively while the native legume Atylosia scarabaeoides recorded with leaf-stem ratio 0.518.

2. Studies on restructured grassland ecosystem with special reference to their consumers.

Studies were continued during the 3rd year on Cenchrus ciliaris pasture fertilised with 60 kg N/ha a day mixed pasture of C. ciliaris + Stylosanthes hamata with 60 kg P₂O₅. Grazing was initiated from 14th August 1985 and continued upto 4th October 1985 with four calves in each compartment of grass and grass-legume pastures. The average live weight gain was higher (385 g/head/day) in the group of animals grazed in mixed pasture as compared to those on the pure pasture. The live weight gain for pure pasture was 203 g/head/day. The dry matter intake was found to be higher (1.80 kg/100 kg body weight) from C. ciliaris pure pasture whereas in mixed pasture the intake was 1.57 kg/100 kg body weight. The herbage utilization was 61.1 and 73.12 percent respectively for mixed and pure pastures for the period.

Grazing studies after three years on sown pastures of Cenchrus ciliaris (pure) as well as mixed pasture of C. ciliaris + S. hamata revealed 13.35% mortality of Cenchrus ciliaris in pure pasture, while remaining 86.65 per cent plants were vigorous indicating higher persistency of Cenchrus ciliaris in Shima-Dichanthium rangelands. However, following invaders were recorded in the above sown pasture of Cenchrus ciliaris with following/percentage frequency of occurrence.

1. Dicanthium annulatum—33 per cent
2. Setaria glauca—26.5 per cent
3. Brachiaria pp—15 per cent
4. Desmostachya binnata—8.5 per cent
5. Heteropogon contortus 2.5 per cent
6. Rhynchosia minima 14.5 per cent. However on overall basis the production of C. ciliaris pure pasture declined by 10.61 percent which is attributable to mortality of plants (13.35 percent) probably due to trampling effect of grazing animal on the stand and destruction of rhizomes of grass by white ants.
As regards the mixed pasture of \( C. \) \textit{ciliaris} + \( S. \) \textit{hamata}, the mortality percentage of grass was 10.35 while that of Caribbean Stylo was 35.6 only. Based on percentage frequency the following invaders were recorded in the mixed pasture of \( C. \) \textit{Ciliaris} + \( S. \) \textit{hamata} in the third year of the experiment: (1) \textit{Dichanthium annulatum}—44.4 percent (2) \textit{Eremopogon faulcolatus}—7.4 percent (3) \textit{Bracharia} sps—22.9 percent (4) \textit{Phaseolus trilobus}—18.5 percent (5) \textit{Atylosia scarabaeoides}—3.8 percent. Herbage production from mixed pasture declined to the tune of 8 and 13.03 percent over a period of three years.

GM-2 EVALUATION, IMPROVEMENT & MANAGEMENT OF NATIVE GRASSLANDS.

2.1. Investigations on the introduction of legumes for improvement of natural grasslands.

1. Studies on the effect of introduction of different range legumes for maximization of grassland productivity in \textit{Eremopogon} community.

(K. C. Kanodia, K. P. Niranjan and S. S. Parihar)

With a view to identify suitable legumes for introduction in \textit{Eremopogon} dominated grassland for improvement of their quality and productivity the experiment was repeated during the third year with six treatments (4 legumes viz. \textit{Atylosia scarabaeoides}, \textit{Macroptilium atropurpureum}, \textit{Stylosanthes hamata} and \textit{S. guianensis} sown in times the recommended doses of fertilizers (40 kg N+20 kg P\textsubscript{2}O\textsubscript{5}/ha) and a control as the degraded native grassland dominated by natural grass \textit{Heteropogon contortus} ecological study was replicated 4 times in R. B. Design in 4 x 3 plots.

Data on plant population and total biomass of legumes established in the grassland (table 19) revealed that there were significant differences due to the introduction of legumes as well as fertilizer application in the grasslands. Highest establishment counts (44583) were recorded for \textit{Atylosia scarabaeoides}.

The forage yield (dry as well as green) was statistically significant due to legume introduction. It was maximum (37.49 q/ha) on dry matter basis in case of Siratro (\textit{Macroptilium atropurpureum}). Amongst the legume introduction the dry matter (31.41 q/ha) was recorded in \textit{S. hamata} and \textit{S. guianensis} respectively. Fertilizer treatment recorded next lower yields (26.74 q/ha) but was superior to that of natural grassland on dry matter basis (15.74 q/ha).
Table 19: Plant population and forage production as affected by legume introduction.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Forage Production (q/ha)</th>
<th>Plant population PP/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Dry</td>
</tr>
<tr>
<td>1.  <em>S. guianensis</em></td>
<td>52.91</td>
<td>31.41</td>
</tr>
<tr>
<td>2.  <em>S. hamata</em></td>
<td>50.83</td>
<td>33.08</td>
</tr>
<tr>
<td>3.  <em>Atylosia</em></td>
<td>54.16</td>
<td>31.74</td>
</tr>
<tr>
<td>4.  Siratro</td>
<td>64.58</td>
<td>37.49</td>
</tr>
<tr>
<td>5.  Fertilizer</td>
<td>43.95</td>
<td>26.74</td>
</tr>
<tr>
<td>6.  Control</td>
<td>25.83</td>
<td>15.74</td>
</tr>
<tr>
<td>SE(m)±</td>
<td>6.75</td>
<td>4.04</td>
</tr>
<tr>
<td>C. D. 5%</td>
<td>20.34</td>
<td>12.05</td>
</tr>
</tbody>
</table>

2. Studies on the effect of time and method of sowing of legumes *Stylosanthes hamata* introduced in the natural *Heteropogon* grassland community.

(K. C. Kanodia, K. P. Niranjan and P. K. Jayan)

These studies were initiated with a view to find out suitable time and method of introduction of an exotic legume, *Stylosanthes hamata* in a natural grassland, with the treatments comprising of three technique of sowing (Broadcasting—*M*₁; Dibbling—*M*₂ and Line sowing—*M*₃) and four times of introduction (May end, Mid June, June end and Mid July). Treatments were replicated thrice in split plot design.
(a) Effect of sowing time: Due to the times of sowing there was very narrow range of variation and differences were nonsignificant for the dry matter production. However, the maximum dry matter yield was recorded (44.96 q/ha) in the plots seeded in June end (S-3), while it was nearly at par i.e. 38.52 & 38.92 q/ha in case of mid June and July middle (S-2 & S-4) treatments respectively. The minimum biomass (34.63 q/ha) was obtained in the plots seeded during May end.

The data on plant population from different sowing dates revealed interesting results, where the maximum establishment of Stylo was (12043/ha) recorded in plots from June end sowing followed by the May end sowing (7,821/ha). The differences among different treatments were found to be significant.

(b) Effect of method of sowing: The different sowing methods did not give statistically significant biomass production. However, the highest dry matter (46.48 q/ha) was obtained due to line sowing. This was followed by 41.75 q/ha in broadcasted plots, while the minimum was obtained (39.69 q/ha) in the dibbled plots. Similarly the highest establishment of legume plants (10332/ha) were recorded in line sowing treatment followed by (7432/ha) in broadcasting and the minimum (5379/ha) in the dibbling method.

The interaction of the operations in different timings revealed distinctly highest dry matter yield (50.64 q/ha) when seeding was carried out in June end through broadcast method, although the maximum plant population was recorded (18,664/ha) with Line sowing during June end.

GM-4 ECOLOGICAL STUDIES OF NATURAL GRASSLANDS

4.5. Ecological studies of different grassland communities of semi-arid regions for increased plant and animal productivity.

(B. K. Trivedi, K. C. Kanodia and N. C. Verma)

Observations were continued during third year on soil moisture botanical composition, plant biomass and body weight gain in Haryana heifers maintained in Sehima Heteropogon grassland community.
Botanical composition: Botanical composition of all the component species was studied through Line Interception method. I. V. I. was computed for dominant, co-dominant perennial and annual grasses, legumes and forbs. Data revealed that I. V. I. of dominant grass (*Schima nervosum*) ranged from 12.6 to 58.7 in defoliated + N and defoliated + P plots.

Plant vigour: The vigour of dominant and co-dominant species was recorded. Most of the vigour attributes (plant height, spike length, total and effective tillers) of both the species showed higher values in grazed plots as compared to defoliated plots. *H. contortus* exhibited a slight increase in plant height after the application of nutrients in defoliated treatments.

Plant biomass: The total plant biomass ranged from 116.2 to 191.2 g/m² in (grazing + P) and (grazing + N) treatment respectively. The major biomass was contributed by grass component of the community.

Secondary productivity: In grazing plots, animals were allowed to graze for 8 hrs per day w. e. f. 4th Oct to 30th Nov. The average increased in the body weight of animal was 10.5 kg/animal @ 181 g/day/animal during a period of 58 days.

Soil Moisture: The soil moisture was recorded in summer (June) and in monsoon (Sept.) period. During summer period soil moisture was more at lower depths in all the treatments, while the trend was reverse during the monsoon period. However, when we compare the moisture status in grazed V/s manually harvested (defoliated) treatments, it was observed that the moisture status was higher in defoliated plots than in grazed plots during the summer season of the year.

4.6 Autecology and growth behaviour studies in different range grasses.

(S. S. Parihar and K. C. Kanodia)

1. The effect of nitrogen and growth period on yields of leaf and stem components in *Chrysopogon fulvus*.
The experiment during the third year continued with 3 levels of nitrogen (0, 45 and 90 kg N/ha) and four growth periods (15, 30, 45 and 60 days). Plots of 4×2.5 m size were replicated three times in randomized block design. The application of nitrogen significantly increased leaf and stem yield per tiller. However, nitrogen fertilizer had more pronounced effect on stem yield per tiller as compared to leaf yield per tiller. Increase in the stem yield was 18.34% and 48.58% with the application of 45 and 90 kg N/ha respectively over the control. While the increase in case of leaf yield was 8.75% and 15.32% with nitrogen levels. Thus, weight of leaf per unit weight of stem significantly decreased with the increasing nitrogen levels but the total number of leaves per tiller was not affected.

Application of nitrogen significantly increased the total dry matter yield. Highest dry forage yield of 45.3 and 48.5 q/ha was recorded at 90 kg N/ha and 60 days of growth respectively. Increasing the growth period from 15 to 30, 30 to 45 and 45 to 60 days also significantly increased the yield of both the components, but particularly in case of stem. This increase in the stem yield was 73.52, 54.87 and 64.04 percent with increasing the growth periods from 15 to 30, 30 to 45 and 45 to 60 days respectively. While in case of leaf yield per tiller this increase was 62.31; 28.57 and 24.21% with the above corresponding growth periods. The maximum percentage increase of both the components was recorded during the growth period of 15 to 30 days.

2. Studies on seed germinability and viability in different cultivars of *Cenchrus ciliaris* and *Cenchrus setigerus*.

(a) Seed germination studies in *C. ciliaris*:

Earlier studies on seed germination and viability with 10 cultivars of *Cenchrus ciliaris* revealed that the seeds (spikelets) maintained some measure of viability up to 48 months, from the data of initial seed collection, when stored under ordinary environmental condition. Therefore, studies were further extended to determine the effect of different packaging material on seed germinability in three strains viz., S-401, S-409 and S-360. Seeds were stored in four different packaging material viz., paper bag, cloth bag, polythene bag and dissicator with calcium chloride. Tests for germinability were conducted at six monthly intervals from the date of initial seed collection. Studies revealed that in case of paper bag, cloth bag and polythene bag, seeds maintained lesser viability up to 48 months only; while in case of dissicator stored seeds, seeds maintained a high measure of viability in all storage periods i. e., up to 60 months. Thus, germination percentage in case of dissicator stored seeds of

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S-401 was found to be 45.66, 45.00, 45.66 42.66 and 35.66 at 12, 24, 36, 48 and 60 months of age. Optimum germination 47.33 to 46.66% was found to be at 12 and 24 months of storage respectively in S-401.

Thus, it is apparent that seeds of C. ciliaris can be stored relatively for longer periods under dry condition.

(b) Seed germination studies with *Cenchrus setigerus*:

Similar studies were also conducted in three strains (S-403, S-410 and S-419) of *Cenchrus setigerus*, to determine the effect of four packaging material during storage. It was found that seeds maintained low viability at 48 months when stored in paper, cloth and polythene bag. Thus germination percentage of S-403 at 48 months of storage was 6.33, 2.0 and 2.33 in polythene, paper and cloth bag respectively. Optimum germination viz., 46.33%, 45.0% and 44.0% was recorded in polythene, paper and cloth bags respectively at 24 months, while dessicator stored seeds showed higher percentage of germination i.e., 42.66%, 46.33%, 43.33%, 36.33%, and 37.66% at 12, 24, 36, 48 and 60 months of storage respectively. No germination was recorded at 60 months in other kinds of packaging materials.

3. Studies on isolation, identification of germination inhibitors in range grasses.

(a) *Dichanthium annulatum*:

Studies were conducted on seed germinability in relation to seed storage, effect of caryopsis from enclosing glumes and nature as well as functions of inhibitors present in the seed. These studies revealed that seeds maintain a considerable high degree of viability up to four years of storage, which decline rapidly during the 5th year of storage. Thus, the percentage germination of seeds at 12, 24, 36, 48 and 60 months of storage was found to be 56.33, 61.33, 50.33, 41.0 and 16.33 respectively.

Removal of caryopsis from the enclosing glumes had an enhanced effect on percentage germination but storing of dehusked seeds (caryopsis) rendered them non-viable indicating that seed enclosing glumes along with the associated phenolic inhibitors are vitally important for preserving the viability of seeds for a longer period of time in nature. Apparently there seem to be two separate systems controlling the germination in *Dichanthium annulatum*. 

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On the one hand there are phenolic inhibitors associated with the seed enclosing glumes which are labile with time decreasing in its effect considerably during storage, and might play a vital role in extending seed viability for a longer period. The other system involves some kind of mechanical restrain imposed by the glumes through reducing oxygen transport to the embryo or check the leaching of the inhibitor.

Studies on the identification of germination inhibitors by chromatography and absorption spectroscopy revealed the presence of cyanidin glycoside and flavonol glycosides.

(b) *Heteropogon contortus* :

Studies were conducted to obtain information on viability and life span of seeds, inhibition of seed germination by spikelet leachate and nature and function of germination inhibitors. Studies on life span of seeds revealed that seeds remain viable upto 60 months of storage when stored under ordinary environmental conditions. However, optimum germination 54.33% and 55.0% was recorded at 12 and 24 months of age respectively.

Earlier studies established that there are germination inhibitors in the spikelet, therefore, studies were further extended to identify the germination inhibitors present in the seed. Methanolic extracts of these spikelets indicated the presence of these spikelet indicated the presence of phenolic compounds, tested through phenolic reagents viz., alcoholic ferric chloride and alcoholic aluminium chloride.

4.7 Studies on geneecological variabilities in rangeland species.

(P. K. Jayan and K. C. Kanodia)

Intraspecific variation met in range grasses and legumes have great ecological significance resulting in ecotypic variation which is inherent in forage species resulting into the continuity of grasslands over broad geographical area of admittedly non-uniform habitats. Therefore, studies with a view of segregating ecological variability met in the grass *Cenchrus ciliaris* and in the legume *Stylosanthes hamata* now naturalised in the semi arid track of Indian sub continent were taken up for investigation. The legume shows great clinal variation in its populations, adapted to different soil, pH conditions and photo periods. Further the ecological races collected from Miami to Coco beach in Florida (N. America) were taken up under provenance trials. Seedlings raised from the seeds were studied for various mor-
Phological and physiological attributes. Growth habit of the populations of the species show variability ranging from prostrate fine leaf to procumbent to erect type. Fourteen races have been recognised based on morphological and physiological attributes. Flowering time (number of days for flowering) in these populations varies from 76 days to 140 days, appears to be a specific character in segregating the population in the species. Autumn growth (both vegetative and reproductive) were noticed in two of the ecological races under study.

On similar lines populations of *Cenchrus ciliaris* were identified and were brought to uniform condition for testing the identity of segregated populations. Some 18 ecotype were thus segregated by transplant experiments and scatter diagram.
DIVISION OF AGROSILVIPASTURE

ASP-1 AUTECOLOGY OF FODDER–CUM–FUEL TREES/SHRUBS.

1.1 Autecology of *Leucaena leucocephala* (Lam) de Wit.

(P. S. Pathak)

1. Comparative growth and biomass production of 12 populations:

At the 3.5 years, the peak height was obtained in Silvi–4 (9.5 m) followed by El Salvador (9.4 m). Maximum variability was obtained in K–8 and *L. diversifolia* while Silvi–4 showed greatest uniformity.

Maximum collar diameter was obtained in K–8 (12.8 cm) followed by K–28 (10.9 cm). K–102 and K–6 showed maximum variability for this character while Silvi–4 remained very stable.

The dbh was found to be maximum in case of K–102 (9.8 cm) followed by K–8 (8.0 cm). K–102 and K–6 showed maximum variability for this character while it was uniform in K–341 and El Salvador.

Maximum bole biomass was obtained in Silvi–4 (16.4 kg/tree) followed by El Salvador (15.7 kg/tree). K–28 and K–6 gave maximum variability for this attribute while K–341 was the most stable.

In these varieties maximum leaf biomass was produced in K–28 and K–102 (2.8 kg/tree) followed by K–8 (2.2 kg/tree).


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Growth and biomass production from coppice shoots:

K-29 produced maximum shoots (10.6/stump) followed by Silvi-4 (10.3). *L. diversifolia* K-102 and K-28 had more stability in regeneration as compared to the other varieties.

The diameter of the coppice shoots was maximum in Silvi-4 followed by K-102, K-67. El Salvador showed more uniformity in the coppice shoot diameter.

The coppice shoot height was maximum in El Salvador (5.9 m) followed by K-28 (5.9 m), K-29, K-28 and *L. diversifolia* showed more uniformity in height growth.

The biomass (FW) produced during thinning after 10 months of harvest was maximum in El Salvador (10.9 kg) followed by K-28 (10.7 kg). The production was highly variable in all the populations.

2. Biomass production as affected by improvement thinning in 4 varieties.

At the end of 6 years the biomass estimations were made during June 1985. At 3 years the improvement felling was done by harvesting alternate rows from 1 x 1 m spacing plantation. Thus, after 3 years the original density of 10,000 plants/ha was reduced to 5000.

Maximum height of 15.4 m was attained by K-72 followed by Silvi-4 (15.2 m). Basal diameter of 14.3 cm was obtained in K-72 followed by 13.0 cm in K-8, dbh followed the similar trend. Bole biomass of 60.2 kg/tree was obtained in K-72 followed by K-8 (59.8 kg/tree). The branch + leaf biomass was maximum in K-8 (15.0 kg/tree) followed by Silvi-4 (14.2 kg/tree). The total aboveground biomass was maximum in K-8 (374.35 t/ha) followed by K-72 (367.9 t/ha). All these traits were minimum in case of cunningham-3.


An experiment was laid out involving 6 inter row and interplant spacing combinations viz., 0.5, 0.75, 1.0, 1.25, 1.5 and 2.0 m planted in systematic design with 2 replications for the treatments with more than 1 rectangularity. The density so obtained, ranged between 2500 to 40,000 plants per ha. At 6 months after planting, the peak height growth was recorded at 1 x 1 m (120.0 ± 23.8 cm) followed by 1.5 x 1.0 m (97.27 ± 24.6 cm) and 1.5 x 1.25 m (96.97 ± 20.65 cm) spacing. The minimum height remained at 0.5 x 0.5 m.
(67.3 ±28.1 cm). The collar diameter growth followed similar trend as of the height. On widely spaced plants the branching net work was more pronounced.

4. Biomass production of 9 populations of marginal lands:

Five populations obtained from Malawi were planted alongwith 4 elite varieties as check on marginal lands at a density of 10,000 plants/ha. Peak biomass with high stability of growth parameters was observed in Silvi-4 (48.5 kg bole/tree) followed by K-8 (43.16 kg bole/tree). The character stability was highest in Silvi-4 while a hybrid between Hawaii x Peruvian was highly variable.

5. Litter production studies:

The litter production studies on the plantations at 10,000 plants/ha density indicated increasing litter production during February and latter half of March with peak during April (131.4g/m²). The litter during April was composed of buds and flowers mostly.

6. Growth of *Leucaena* species with other germplasm:

In the exotic 17 *Leucaena leucocephala* germplasm alongwith 3 species viz., *L. diversifolia*, *L. collinsii* and *L. pulverulenta*, K-8 gave peak diameter and height growth followed by *L. diversifolia*.

1.2. Autecological studies on *Albizia* spp. and *D. cinerea*.

(M. M. Roy)

(A) *Albizia* spp. (*A. amara*, *A. lebbek* and *A. procera*)

1. Effect of temperature on seed germination:

Germination in many tree seeds can occur over a rather wide range of temperatures, but in order to standardise the optimum range of temperatures for these species the experiment was performed in controlled dark conditions with six treatments viz., 27±2°C continuous (T₁); 37±2°C continuous (T₂); 12 hr. 27±2°C alternate with 12 hr. room temp. (T₃); 12 hr. 37±2°C alternate with 12 hr. rocm temp.; 40±2°C continuous and room temp. (the experiment was performed in the 2nd week of Jan. 85). The experiment was continued upto 14th day.

In case of *A. amara* and *A. lebbek* maximum germination and seedling vigour was in the T₆ followed by T₃. It, therefore, appears that these seeds prefer comparatively lower
temp. range with considerable temp. fluctuations. In case of *A. procera*, however, T₃ and T₁ treatments gave more germination and seedling vigour showing that these seeds prefer comparatively higher temperature range with moderate temp fluctuation. The temp in the range of 40 °C and above have shown inhibitory effect on seed germination in all the species—the extreme being *A. procera*.

2. **Effect of light (Red and Far Red interactions) on seed germination:**

Very little information is available about the effects of light on germination of tree seeds. In an earlier study it has been shown that seed germination in continuous fluorescent light is indifferent in case of *A. procera* whereas in the other 2 species there has been a stimulating effect (Roy, 1981). Under seven treatments viz., continuous dark (T₁); red 24 hr then continuous dark (T₂); far red 24 hr then continuous dark (T₃); red 24 hr followed by far red 24 hr then continuous dark (T₄); far red 24 hr followed by red 24 hr then continuous dark (T₅); continuous red (T₆); continuous far red (T₇), the germination experiments were performed. *A. procera* showed indifference to various treatments while the red light seemed to promote seed germination, in this temp. range, in *A. lebbek* and *A. amara*.

3. **Effect of GA treatment on seedling growth of *A. lebbek***.

The effect of lower doses of GA in *A. lebbek* were studied in nursery conditions with six treatments viz., control (T₁), 10 ppm (T₂), 15 ppm (T₃), 20 ppm (T₄), 50 ppm (T₅) and 100 ppm (T₆) sprayed as foliar. The application of lower range viz. 10-15 ppm induced a promotive effect on growth and dry weights of shoot and root.

4. **Effect of L-AA treatment on seedling growth of *A. amara***.

The effect of lower doses of L-AA on seedling growth of *A. amara* were studied in nursery conditions with six treatments viz., control (T₁), 10 ppm (T₂), 15 ppm (T₃), 20 ppm (T₄), 50 ppm (T₅) and 100 ppm (T₆) applied as foliar spray. At 50 ppm a promotive effect on growth and dry weights of shoot and root was observed.

(132)
(B) *D. cinerea*

1. **Effect of temp. on seed germination.**

   In this case germination occurred over a wide range of temp even in the range 40 ± 2°C. However, maximum germination was recorded in 37—20°C and 37 ± 2°C treatments.

2. **Effect of GA on seed germination.**

   The seeds of this species were allowed to germinate in controlled dark conditions (temp 27±3°C) at six concentrations control (T₁), 50 ppm (T₂), 100 ppm (T₃), 150 ppm (T₄), 200 ppm (T₅) and 250 ppm (T₆). The lower range of GA was found to promote seed germination though there was not much difference in the radicle growth with maximum at 200 ppm.

1.3. **Autecological studies on exotic multiple purpose shrubs/trees.**

   (P. S. Pathak)

   During the year the *Sesbania sesban* plantations were evaluated for their growth and production parameters and the germplasm of multiple purpose trees was studied at nursery and field level for growth and phenology.

   (a) *Sesbania sesban* :

   The plant height attained was significantly variable in 13 collections with maximum in No. 6 (5.3 m) followed by 2 (5.0 m) and the minimum in 1 (2.1 m). The collar diameter also showed significant variability with peak in 2 (6.5 cm) followed by 6 (6.4 cm) and the minimum in 1 (1.8 cm). Dbh was highly variable since it was a highly branched perennial. Thus, only dbh of the leading shoot was measured for comparison which showed significantly different dbh with peak in 2 (3.30 cm) followed by 6 (2.8 cm) and the minimum in 1 (0.6 cm). Branching and hay characters were highly variable between different varieties.

   **Production characteristics :**

   It was observed that No. 13 (11.4 kg/tree) gave maximum production followed by No. 2 (4.5 kg/tree). The minimum was in No. 5 (2.3 kg/tree). No. 1 by this time did not survive. No. 10 gave maximum variability in the production.
(b) Initial testing of the multiple purpose tree germplasm:

In the twenty three exotic woody perennial germplasms received from Oxford Forestry Institute 11 more plant species were added as local control. Their emergence percent and growth in height and basal diameter are presented in table 20.

Table 20: Field emergence and growth characteristics of multiple purpose shrubs/trees.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Species</th>
<th>Emergence (%)</th>
<th>Growth basal dia (Cm)</th>
<th>Growth at 6 months height (Cm)</th>
<th>Growth basal dia (Cm)</th>
<th>Growth at 6 months height (Cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Acacia tortilis</td>
<td>65.0</td>
<td>0.48</td>
<td>48.0</td>
<td>0.48</td>
<td>58.4</td>
</tr>
<tr>
<td>2.</td>
<td>A. aneura</td>
<td>38.0</td>
<td>0.20</td>
<td>11.0</td>
<td>0.25</td>
<td>16.0</td>
</tr>
<tr>
<td>3.</td>
<td>A. pennatula</td>
<td>42.9</td>
<td>0.94</td>
<td>95.0</td>
<td>1.20</td>
<td>114.4</td>
</tr>
<tr>
<td>4.</td>
<td>A. deamii</td>
<td>15.0</td>
<td>0.48</td>
<td>58.0</td>
<td>0.48</td>
<td>68.0</td>
</tr>
<tr>
<td>5.</td>
<td>A. farnesiana</td>
<td>20.0</td>
<td>0.60</td>
<td>82.0</td>
<td>0.68</td>
<td>92.6</td>
</tr>
<tr>
<td>6.</td>
<td>A. mangium</td>
<td>56.0</td>
<td>0.34</td>
<td>22.0</td>
<td>0.38</td>
<td>32.8</td>
</tr>
<tr>
<td>7.</td>
<td>Albizia lebbek</td>
<td>61.0</td>
<td>0.44</td>
<td>22.0</td>
<td>0.44</td>
<td>27.6</td>
</tr>
<tr>
<td>8.</td>
<td>A. amara</td>
<td>55.0</td>
<td>0.22</td>
<td>28.0</td>
<td>0.40</td>
<td>35.8</td>
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<tr>
<td>9.</td>
<td>A. procera</td>
<td>60.0</td>
<td>0.50</td>
<td>27.0</td>
<td>0.48</td>
<td>35.8</td>
</tr>
<tr>
<td>10.</td>
<td>A. caribaeae</td>
<td>42.5</td>
<td>0.36</td>
<td>26.0</td>
<td>0.32</td>
<td>32.6</td>
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<tr>
<td>11.</td>
<td>A. ganchepele</td>
<td>20.0</td>
<td>0.90</td>
<td>45.0</td>
<td>1.04</td>
<td>52.0</td>
</tr>
<tr>
<td>12.</td>
<td>Prosopis juliflora</td>
<td>50.0</td>
<td>0.48</td>
<td>46.0</td>
<td>0.50</td>
<td>55.6</td>
</tr>
<tr>
<td>13.</td>
<td>P. juliflora (UP Forest)</td>
<td>65.0</td>
<td>0.45</td>
<td>59.0</td>
<td>0.50</td>
<td>69.8</td>
</tr>
<tr>
<td>14.</td>
<td>J. juliflora (CAZRI)</td>
<td>50.0</td>
<td>0.34</td>
<td>36.0</td>
<td>0.48</td>
<td>44.6</td>
</tr>
<tr>
<td>15.</td>
<td>M. temuiflora</td>
<td>20.0</td>
<td>0.15</td>
<td>12.0</td>
<td>0.15</td>
<td>15.5</td>
</tr>
</tbody>
</table>

(134)
<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td><em>Pithecellobium dulce</em></td>
<td>70.0</td>
<td>0.64</td>
<td>57.0</td>
<td>0.64</td>
<td>67.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td><em>Enterolobium cyclocarpum</em></td>
<td>47.5</td>
<td>0.84</td>
<td>76.0</td>
<td>0.98</td>
<td>86.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td><em>Leucaena shanoni</em></td>
<td>32.5</td>
<td>0.76</td>
<td>110.0</td>
<td>0.78</td>
<td>134.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td><em>L. diversifolia</em></td>
<td>60.0</td>
<td>1.08</td>
<td>150.0</td>
<td>1.26</td>
<td>202.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td><em>L. leucocephala</em></td>
<td>90.0</td>
<td>1.04</td>
<td>125.0</td>
<td>1.24</td>
<td>147.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td><em>L. leucocephala</em> (Silvi-4)</td>
<td>35.0</td>
<td>0.92</td>
<td>125.0</td>
<td>1.14</td>
<td>133.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td><em>L. diversifolia</em> (IGFRI)</td>
<td>80.0</td>
<td>0.66</td>
<td>92.0</td>
<td>0.70</td>
<td>105.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td><em>L. leucocephala</em> × <em>L. diversifolia</em></td>
<td>75.0</td>
<td>0.82</td>
<td>84.0</td>
<td>1.14</td>
<td>89.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td><em>L. leucocephala</em> × <em>L. diversifolia</em></td>
<td>37.5</td>
<td>0.68</td>
<td>52.0</td>
<td>0.85</td>
<td>87.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td><em>L. leucocephala</em> × <em>L. diversifolia</em></td>
<td>80.0</td>
<td>0.76</td>
<td>73.0</td>
<td>0.95</td>
<td>122.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td><em>Apoplenesis peniculata</em></td>
<td>20.0</td>
<td>0.77</td>
<td>95.0</td>
<td>1.05</td>
<td>120.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td><em>Mycospermum frutescense</em></td>
<td>30.0</td>
<td>0.30</td>
<td>18.0</td>
<td>0.30</td>
<td>24.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td><em>Atelia herbert smithii</em></td>
<td>50.0</td>
<td>0.30</td>
<td>11.0</td>
<td>0.25</td>
<td>11.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td><em>Gliricidia sepium</em></td>
<td>65.0</td>
<td>1.28</td>
<td>95.0</td>
<td>1.54</td>
<td>129.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td><em>Parkinsonia aculeata</em></td>
<td>52.5</td>
<td>0.82</td>
<td>105.0</td>
<td>0.94</td>
<td>122.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td><em>Hematoxylon brasiletto</em></td>
<td>30.0</td>
<td>0.54</td>
<td>65.0</td>
<td>0.62</td>
<td>75.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td><em>Senna atomaria</em></td>
<td>27.5</td>
<td>0.58</td>
<td>40.0</td>
<td>0.64</td>
<td>43.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td><em>Caeselpinia ereostachys</em></td>
<td>77.5</td>
<td>0.68</td>
<td>38.0</td>
<td>0.58</td>
<td>46.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td><em>Crescentia alata</em></td>
<td>40.0</td>
<td>0.78</td>
<td>40.1</td>
<td>1.18</td>
<td>43.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(135)
2.1 Silvipastoral studies on fodder-cum-fuel trees.

(R. Deb Roy, S. K. Gupta and T. A. Khan)

This is a long term study on the growth and production of *Acacia tortilis* in association with two *Cenchrus* pastures. In half of the area all the trees were harvested during July/Aug 1984. During the year under report, rooted slips of *Cenchrus ciliaris* were transplanted and studies carried out on coppice shoots besides growth and pasture production in the other half of the existing silvipastoral plantation.

Studies on coppice growth:

Number of coppice shoots per stool varied from 5-17, the maximum number of shoots were observed in the wider tree spacing and in association with *C. setigerus* pasture. In one year the maximum mean height and collar diameter of the coppice shoots recorded was 2.45 m and 3.1 cm respectively and was observed in wider tree spacing and in association with *C. ciliaris* pasture.

Growth attributes of the trees:

Studies on growth in height, CD and Dbh recorded in the remaining half of the area revealed that the maximum mean annual increment in height, CD and Dbh was 64 cm, 1.7 cm and 1.9 cm respectively. The maximum height, CD and Dbh recorded was 8.96 m, 23.6 cm and 26.6 cm respectively. Variation in various growth parameters are not statistically significant although higher diameter growth both in CD as well Dbh was observed under wider tree spacing and in association with *Cenchrus* pasture compared to control.

The above findings indicate no appreciable affect of pasture species on the growth of *Acacia tortilis*.

Pasture production:

Forage production in general was slightly higher in the open compared to that under closed tree canopy. Forage production from *C. ciliaris* was more compared to the *C. setigerus*. Forage production was higher under wider tree spacing compared to those under narrower
tree spacing. Inspite of some biotic interferences the maximum dry forage production of 2.49 t/ha was recorded in *C. ciliaris* under the closed canopy of *A. tortilis* at wider tree spacing. Under the open canopy, the forage production in the same treatment combination was 2.65 t/ha.

Wood yield and volume:

On the basis of the sample trees harvested during 1984, the maximum total wood yield (Bole+branches) per tree was 363.6 kg giving annual wood yield of 8.7 t/ha/annum.

On the basis of the diameter at breast height (Dbh) and height, attempt was made to study several models for predicting volume of the bole and also total wood yield. For bole volume upto 2 metre for finding out small timber, the equation \(V=9226.455+15.509 D^2-I\) \((R^2=0.942)\) gave best fit for *Acacia tortilis*.

For total wood yield \(Y=-63.8436+10.8356 D\) \((R^2=5865)\) was found to give the best fit.

### 2.2 Studies on the establishment and growth of plantation species under various silvipastoral combinations.

(R. Deb Roy and S. K. Gupta)

During the year under report, studies were carried out on various growth parameters like height, collar diameter (CD), diameter at breast height (Dbh) of *Hardwickia binata* and *Albizia amara* in association with *Cenchrus ciliaris*, *Stylosanthes hamata* and a mixture of *Chrysopogon fulvus* and *Sehima nervosum* with *S. hamata*. Studies were also carried out on pasture production under the canopy of above trees.

Growth: Growth in height, CD and Dbh of *H. binata* and *A. amara* under various combinations are presented in table 21. Height growth in general was higher with *H. binata* compared to *A. amara*. Collar diameter growth in general was higher in *A. amara* compared to that of *H. binata*. In both the tree species height growth and growth in CD was affected by the spacing treatments. Higher growth in CD was observed with wider tree spacing especially in case of *H. binata*, whereas higher growth in height was observed in narrower spacings.
Growth in Dbh in general was much higher in *A. amara* compared to *H. binata* mainly because of characteristic low branching habit of former. In both the species maximum growth in Dbh was found in wider tree spacings.

**Forage production:**

Pasture production was affected due to biotic interference in some of the pots. The maximum green forage and dry forage production of 6.17 and 2.76 t/ha was observed in *C. ciliaris*—Stylo pasture growth under the canopy of *A. amara* at a spacing of 6 m × 4 m followed by a mixture of *C. fulus* and *S. nervosum* (4.82 and 2.16 t/ha respectively) under the canopy of *H. binata* at wider spacing. Forage production in general was higher with wider tree spacing.

Table 21: Growth in height, CD and Dbh of *Albizia amara* and *Hardwickia binata* under various treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Height (m)</th>
<th>C. D. (cm)</th>
<th>Dbh (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>A. amara</em></td>
<td><em>H. binata</em></td>
<td><em>A. amara</em></td>
</tr>
<tr>
<td><em>C. ciliaris</em></td>
<td>6.17</td>
<td>6.57</td>
<td>20.98</td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chrysopogon—Sehima</td>
<td>5.87</td>
<td>6.66</td>
<td>19.88</td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (No pasture)</td>
<td>6.22</td>
<td>6.81</td>
<td>20.54</td>
</tr>
<tr>
<td>Mean</td>
<td>0.09</td>
<td>6.68</td>
<td>20.47</td>
</tr>
<tr>
<td>SE(m)</td>
<td>0.11</td>
<td>0.07</td>
<td>0.32</td>
</tr>
</tbody>
</table>
2.2. Increasing production potential of wastelands through silvipastoral systems

(R. Deb Roy, P. S. Pathak and S. K. Gupta)

This is a long term study on the establishment, growth and productivity of various silvipastoral systems. Studies revealed that if managed scientifically, pasture in some of the systems can be fairly productive even after eight years of establishment. During the year *Cenchrus* pasture was re-established under the canopy of eight year old plantation. Data on growth and pasture production under different silvipastoral systems are given in table 22 & 23.

Table 22: Growth of tree component under different silvipastoral systems (9th year)

<table>
<thead>
<tr>
<th>System</th>
<th>Tree component</th>
<th>Association</th>
<th>Growth (m)</th>
<th>Growth (cm)</th>
<th>Growth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td><em>D. cinerea</em>¹</td>
<td><em>C. ciliaris &amp; C. fulvus</em></td>
<td>3.7</td>
<td>8.5</td>
<td>7.5</td>
</tr>
<tr>
<td>II</td>
<td><em>L. leucocephala</em></td>
<td>-do-</td>
<td>7.5</td>
<td>12.8</td>
<td>11.5</td>
</tr>
<tr>
<td>III</td>
<td><em>A. lebbek</em></td>
<td>-do-</td>
<td>8.9</td>
<td>22.6</td>
<td>21.3</td>
</tr>
<tr>
<td>IV</td>
<td><em>A. lebbek</em></td>
<td><em>S. nervosum &amp; C. ciliaris</em></td>
<td>9.7</td>
<td>21.4</td>
<td>17.8</td>
</tr>
<tr>
<td>V</td>
<td><em>A. procera</em></td>
<td><em>C. ciliaris</em></td>
<td>9.7</td>
<td>21.4</td>
<td>17.7</td>
</tr>
<tr>
<td>VI</td>
<td><em>Prosopis Juliflora</em></td>
<td><em>C. ciliaris</em></td>
<td>5.3</td>
<td>13.7</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td><em>Pilhecollobium dulceae</em></td>
<td>-do-</td>
<td>5.8</td>
<td>15.8</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td><em>Acacia tortilis</em></td>
<td><em>C. fulvus</em></td>
<td>7.3</td>
<td>16.6</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td><em>A. nilotica</em></td>
<td>-do-</td>
<td>9.5</td>
<td>23.6</td>
<td>23.4</td>
</tr>
<tr>
<td>VII</td>
<td><em>A. lebbek</em></td>
<td>natural pasture</td>
<td>8.9</td>
<td>24.3</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td><em>B. racewosa</em></td>
<td>-do-</td>
<td>5.4</td>
<td>16.8</td>
<td>17.4</td>
</tr>
</tbody>
</table>

¹ introduced in established pasture during 1982
Table: 23—Pasture production under different silvipastoral systems

<table>
<thead>
<tr>
<th>System</th>
<th>Tree canopy</th>
<th>(in t/ha)</th>
<th>Natural grass</th>
<th>C. ciliaris</th>
<th>C. fulvus</th>
<th>S. nervosum</th>
<th>Siy</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>D. cinerea</td>
<td>6.60</td>
<td>2.80</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>II</td>
<td>L. leucocephala</td>
<td>3.35</td>
<td>2.78</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>III</td>
<td>A. lebbek</td>
<td>2.32</td>
<td>3.16</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>IV</td>
<td>A. lebbek</td>
<td>3.04</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>V</td>
<td>A. procera</td>
<td>2.25†</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VI</td>
<td>P. juliflora</td>
<td>2.70</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Pithecellobium dule</td>
<td>2.30</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>1.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 This is newly established pasture (one year old)

The lopping of *D. cinerea* in system I provided 1.04 t/ha/year of additional dry fodder thus providing total of 4.64 t/ha/yr mixed dry fodder. It has also been possible to grow *Leucaena* under the canopy of 8-9 yr old plantation of *A. lebbek* (Syst VII) at 250-280 trees/ha density. *C. ciliaris* was also successfully re-established (Syst V) under the canopy of *A. procera* (200-250 t/ha).

2.3. Silvipastoral studies on *D. cinerea* and *Albizia* spp.

(M. M. Roy)

1. (a) Mortality of plants over a period of 4 1/2 year was around 10%. No significant effect of various treatments was recorded in the mortality percent.
(b) Average growth of plants in 4.5 year period was rated as medium. Average height and collar diameter attained during this period were 313 cm and 4.9 cm respectively. It appears that during this period more increment has taken place in primary growth and branching rather than secondary growth. Flowering was recorded in all well grown plants. Flowering seems to be linked with a particular level of vegetative growth. The plantlets around the trees have also become much more pronounced in this period.

(c) Forage production data from these silvipastoral systems ranged widely from 1.33 t (dry)/ha/annum to 4.12 t (dry)/ha/annum (Table 24).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nov 1985 (Total production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+C. c.</td>
<td>3.72</td>
</tr>
<tr>
<td>D+C. f.</td>
<td>1.79</td>
</tr>
<tr>
<td>D+C. c.+St.</td>
<td>4.12</td>
</tr>
<tr>
<td>D+C. c.+Si.</td>
<td>3.47</td>
</tr>
<tr>
<td>D+C. f.+St.</td>
<td>2.52</td>
</tr>
<tr>
<td>D+C. f.+Si.</td>
<td>1.98</td>
</tr>
<tr>
<td>D+St.</td>
<td>2.79</td>
</tr>
<tr>
<td>D+Si.</td>
<td>1.33</td>
</tr>
</tbody>
</table>

D = Dichrostachys cinerea, C. c. = Cenchrus ciliaris,
C. f. = Chrysopogon fulvus, St. = Stylosanthes hamata,
Si = Macroptilium atropurpureum (Siratro),

(141)
The wide variations in forage production may be ascribed mainly to poor establishment and subsequent mortality of *Chrysopogon fulvus* and Siratro. The overall production was also on a decline than the production obtained upto 1984.

(d) Performance of *C. ciliaris* among grasses and *S. hamata* among the legumes was continued to be better in terms of yield and establishment on such wastelands. Among grass-legume mixture, *C. ciliaris* and *S. hamata* combination was better than the other ones.

2. Studies on forage and fuel production obtainable from *D. cinerea* have shown following broad conclusions so far.

(a) Half lopping treatment at six-monthly interval continued to give quite consistent production from regenerated shoots. About 2.9 kg wood and 2.5 kg leaf on fresh weight basis per tree may be expected from such lopping management systems. The fodder to fuel ratio increased from 0.78 to 0.86. Though not much difference was there in the height of regenerated shoots, there was a reduction in the diameter of the regenerated shoots by about 12%. The number of sub-branches on the regenerated shoots increased by about 20%. The plant becomes more compact in shape.

(b) Around several lopped plants, number of plantlets around the mother plants were more compared to unlopped plants. This suggests that any kind of injury to the main plant gives a stimulus to the ability of the plant to expand horizontally.

3. *Albizia* spp.

Studies on forage and fuel production obtainable from *Albizia amara*, *A. lebbek* and *A. procera* under different lopping management systems were continued. The work on the quality parameters of lopped leaves in different seasons were also taken up. Lopping at yearly interval seems to be feasible in these species. Studies are under progress so as to standardise the lopping intensity and initial age for lopping.

2.4 Silvipastoral studies on *Dalbergia sissoo*, *Hardwickia binata* and *Acacia* species.

(S. K. Gupta, P. S. Pathak and R. Deb Roy)

1. *Acacia* species:

The experiment was planted on calcareous wastelands during July 1983 with two
species of Acacia viz., A. tortilis and A. nilotica in 3×2 m spacing in alternate plant management system.

This year too A. nilotica continued to produce a wide difference in its growth rate under the two plant arrangement systems. Under alternate plant system, these species gave 5.39 per cent more survival, 94.49 cm more height and 1.25 cm more collar diameter compared to alternate line arrangement. In case of A. tortilis, more growth in terms of height (37.2 cm) and C. D. (+0.32 cm) was recorded in alternate plant management system. However, survival of these species was cent per cent in alternate line management system while it was 79.41 per cent in the other systems. The A. nilotica exhibited better growth compared to A. tortilis on such wastelands.

The production potential of the natural grasses during December 1985 was found to be around 4.5 t/ha (green) and 2.47 t/ha (dry).

Table 25: Performance of A. nilotica and A. tortilis on calcareous wastelands at 2 1/2 year.

<table>
<thead>
<tr>
<th></th>
<th>A. nilotica</th>
<th>A. tortilis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ALM</td>
<td>APM</td>
</tr>
<tr>
<td>Survival percentage</td>
<td>91.67</td>
<td>97.06+5.39</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>105.27</td>
<td>199.76+94.49</td>
</tr>
<tr>
<td>C. D. (cm)</td>
<td>1.07</td>
<td>2.32+1.25</td>
</tr>
</tbody>
</table>

ALM=Alternate line management.

APM=Alternate plant management

2. Hardwickia binata and Dalbergia sissoo:

The study on Hardwickia binata and Dalbergia sissoo on moist marginal wasteland system gave comparatively poor response for growth at the 4 1/2 year of study. Maximum growth in terms of height (161.75 cm) and collar diameter (2.64 cm) was recorded from H. binata pure plantation.
Performance of *Leucaena leucocephala* on this site on short rotation basis at comparatively drier region was better than *H. binata* and *D. sissoo* which exhibited average height, CD and Dbh growth of 5.72 m, 7.77 cm and 5.32 cm respectively.

Forage production from grasses and legumes under such system was also studied. Para grass which was planted at the start of the experiment continued to give maximum green forage 10.9 t/ha/yr and dry forage 3.57 t/ha/yr. Similarly *Stylosanthes* gave 66 t/ha/yr green forage and 2.2 t/ha/yr dry forage. The production therefore seems to be on decline showing thereby the need for reseeding of this species after this period.

On comparatively drier sides natural grasses were allowed to grow. Major fraction of these was *Ischilema* giving production of 5.7 t/ha/yr forage and 3.17 t/ha/yr. Dry forage production of other grasses was recorded to be 3.96 t/ha/yr of green and 2.44 t/ha/yr dry.

### ASP-3 AGROFORESTRY STUDIES FOR SELECTION OF COMPATABLE TREE SPECIES FOR OPTIMUM PRODUCTION.

#### 3.1. Effect of row orientation of *L. leucocephala* on the production of forage, fuel and grain.

(P. S. Pathak)

1. Oats and Berseem were taken in between the alleys. The peak production continued to be obtained in the angular directions. The crop lines adjacent to the trees were more robust and productive. During the rainy season, the sorghum sown in between the alleys, recorded peak growth in open plots compared to the alleys. The shade effects were much pronounced with its maximum in E-W direction. The crop has been followed by oats crop in *rabi* season.

2. In forage forestry trial with *L. leucocephala* and guinea grass more than 70 t/ha green fodder has been recorded.
5.1. Study of genetic architecture and effect of mutagens in *L. leucocephala* in relation to production of forage and fuel

(V. K. Gupta)

1. Heterosis and inbreeding depression in *Su-babool* (*Leucaena leucocephala* [Lam] de wit).

Ten cultivars of *su-babul*, representing contrasting agronomic characters, 10 F₁ and 10 F² were transplanted in first week of August 1982 in randomised block design. The analysis of variance of generation means revealed significant differences among the parents, F₁ and F² generations for all the attributes.

Several crosses in F₁ and F² had better yield than the best parent. Heterosis over mid and over better parent were not significant. In general, high inbreeding depression was associated with high heterotic effect in most of the crosses. Inbreeding depression ranged from 74.44 (IGFRI-18 × IGFRI-24) to 47.58 (IGFRI-7 × IGFRI-29) per cent. Five out of ten crosses had inbreeding depression in positive direction. However, F₁ mean of none of the crosses had significantly differed from F² mean.

None of the crosses in F₁ and F² generations had better yield than the best parent. However, Heterosis over mid parent ranged from 16.44 to 74.64 per cent and over better parent from 32.52 to 70.24 per cent. Only one cross i.e., IGFRI-18 × IGFRI-25 had significantly higher fuel-wood yield than their respective better parents. Most of the crosses had positive signs of magnitude of inbreeding depression. However, significant value was observed only in IGFRI-18 × IGFRI-25 which also had significant magnitude of better parent heterosis. Average inbreeding depression for this trait was 9.95 per cent.

2. Evaluation of the performance of hybrids and study of hybrid vigour in *Su-babul* (*Leucaena leucocephala*).

Eight parents, representing contrasting agronomic characters and their twenty eight hybrids were transplanted in last week of July 83 in randomised block design with three replications to study the hybrid vigour and evaluate performance of hybrids.
Among the hybrids, maximum firewood yield was obtained by a cross IGFRI 18-5 × IGFRI 31-2 (17.27 kg/plant), a cross Peru × Peru type followed by IGFRI 31-2 × IGFRI 31-4 (17.07 kg per plant), a cross of Peru × Salvador type. Hybrid vigour for this trait ranged from 79.17 to 57.00 per cent over better parent and from 66.82 to 71.08 per cent over mid parent. None of the the cross was better than the best parent in the trial. Heterosis over better parent was significant and positive in one cross i. e., IGFRI 18-5 × IGFRI 31-2, while it was significant in two crosses i. e. IGFRI 29-1 × IGFRI 30-7 and IGFRI 18-5 × IGFRI 31-2 when estimated over mid parent.

IGFRI 18-5 × IGFRI 31-2 had highest forage yield of 8.27 kg per plant. This cross exceeded even the best parent in the trial by 14.38 per cent. Mid parental heterosis ranged from -59.02 to 124.12 per cent while heterosis over better parent ranged from -72.33 to 85.01 per cent. Means of four crosses i. e., IGFRI 8-3 and IGFRI 29-1 × IGFRI 30-7 were significantly greater than their respective mid parent value. Heterobeltosis were positive and significant in one cross (IGFRI 18-5 × IGFRI 31-2) for collar diameter, in two crosses (IGFRI 31-2 × IGFRI 33-2 and IGFRI 29-1 × IGFRI 30-7) for diameter at breast height, and in three crosses (IGFRI 33-2 × IGFRI 31-2, IGFRI 29-1 × IGFRI 8-3 and IGFRI 29-1 × IGFRI 30-7) for branch weight per plant. Plant height did not exhibit significant and positive magnitude of heterosis over better parent in any of the crosses under trial.


Nine species of genus Leucaena viz., L. leucocephala, L. diversifolia, L. lanceolata, L. shannoni, L. esculenta, L. trichodes, L. pulverulenta, L. macrophylla and L. retusa and two interspecific hybrids of L. leucocephala × L. pulverulenta were transplanted in July 1983 in randomised block design with two replications. All plants of L. retusa and L. esculenta died. Survival percentage of L. diversifolia (78-49 79°C), L. pulverulenta (K-75), L. trichodes (78-86) were poor. L. lanceolata, L. leucocephala, L. macrophylla, L. diversifolia (K-156) performed well among species. Performance of both the interspecific hybrids were good.


Eighteen selections with K-8 and K-28 were planted in July 1983 in irrigated and unirrigated areas in randomised block design with three replications. Growth in unirrigated area was not satisfactory due to fire accident in summer 1984. No observation, therefore, was recorded.
Four selections i.e., S-10, S-11, S-14 and S15 were significantly higher than the best check K-8 for main stem weight per plant. Highest main stem weight of 36.13 kg and leaf weight of 10.75 kg per plant were recorded with S-10. Three selections i.e., S-10, S-11 and S-14 had significantly higher magnitude for leaf weight, plant height, DBH and CD than the best check.

5. Evaluation of new introductions of *L. leucocephala* received in year 1984 with K-8, K-28 and IGFRI 23-1

Twenty seven new lines of *L. leucocephala* received during 1983-84 from various places were planted in July 1984 with K-8, K-28 and IGFRI 23-1 with the objectives to assess their performance in comparison to existing varieties and for desirable characteristics.

None of them was better than best check IGFRI 23-1 in respect of collar diameter and plant height. Late flowering and few pods set in lines IGFRI-99 (K-72), IGFRI-102 (K-636), IGFRI-103 (K-341), IGFRI-106 (Peru type) and IGFRI 23-1 (Salvador type). Disease gummosis was not observed in any lines this year.


Four strains of *L. diversifolia*, two of *L. pulverulenta*, one each of *L. macrophylla*, *L. collinsii*, *L. esculenta*, *L. insularum*, *L. shannoni* and four strains of *L. leucocephala* were sown in March 1985 in nursery and transplanted in field in July 1985.

Highest plant height was recorded *L. macrophylla* (65.29 cm) followed by *L. leucocephala* cv. CPI 61227/109 (61.00) and cv. CPI 33029/110 (60.56). Performance of *L. diversifolia* cv. K-156 and CPI 46568 were also good. *L. macrophylla* had highest magnitude for number of leaves per seedling (13.40). In case of length of leaf, *L. diversifolia* K-156 and *L. pulverulenta* (K-19) had maximum magnitude of 14.50 cm.

*L. leucocephala* strain cv. CPI 61227/109 had highest height of 184.00 cm followed by *L. leucocephala* strain Peru, *L. diversifolia* strain K-156, *L. insularum* and *L. collinsii* attained in 9 months.

7. Identification of compatible plants within species for pure seed production and percentage of pure plants in open pollinated seeds
Since all species of genus *Leucaena* were self incompatible except *L. leucocephala* and K-156 in *L. diversifolia*, there is a need to search compatible plants within the species. Compatible plants were identified in *L. lanceolata* and *L. shannonii* and all the plants of crossed seeds were true type. Open pollinated seeds of all species were raised in July 85 to see percentage of true type trees within species. In *L. lanceolata*, *L. diversifolia* (K-156), *L. shannonii*, near about 50 per cent plants appeared to be pure. Confirmation can be possible after flowering and pod setting.

8. Selection of desirable plants in F² populations and study of genetic parameters including hybrid vigour and inbreeding depression in *L. leucocephala*

Seventeen F² generations and their eight parents and F¹ were transplanted in July 85 in randomised block design with three replications. Among F² populations, progenies of crosses IGFRI 33–2×IGFRI 31–2, IGFRI 29–1×IGFRI 31–2, IGFRI 18–5×IGFRI 8–3, IGFRI 31–2×IGFRI 11–4, IGFRI 23–1×IGFRI 31–2, IGFRI 33–2×IGFRI 11–4 and IGFRI 31–2×IGFRI 11–4 were good. Forty eight plants among these progenies were better than K-8.

ASP–6 : AGRO–SILVI–FORAGE PRODUCTION STUDIES FOR MAXIMISING PRODUCTION OF QUALITY FODDER.

6.1. Development of Agro-Silvi-forage production system in relation to conventional systems under rainfed conditions.

(D. S. Chauhan)

In the study initiated during July 1984 for developing a new system for optimising production of quality fodder, seven combinations were tried for 3 cropping seasons i. e., till October 1985.

The data on fodder production (green, dry and crude protein content (individual and in herbage mixture) are presented in table–26.
Table 26: Fodder yield and protein content in different Agro-silvi-forage production system under rainfed conditions.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Green fodder (q/ha)</th>
<th>Dry matter (q/ha)</th>
<th>Crude protein (q/ha)</th>
<th>Crude protein content in composite herbage mixture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cenchrus</td>
<td>182.54</td>
<td>55.67</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Stylo</td>
<td>91.66</td>
<td>18.51</td>
<td>3.05</td>
<td></td>
</tr>
<tr>
<td>Subabool</td>
<td>54.84</td>
<td>17.27</td>
<td>3.45</td>
<td></td>
</tr>
<tr>
<td>Shevari</td>
<td>90.08</td>
<td>30.17</td>
<td>4.82</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>419.12</td>
<td>121.62</td>
<td>15.32</td>
<td>12.59</td>
</tr>
<tr>
<td>2. Jowar</td>
<td>359.53</td>
<td>97.64</td>
<td>7.32</td>
<td></td>
</tr>
<tr>
<td>Subabool</td>
<td>55.15</td>
<td>17.37</td>
<td>3.47</td>
<td></td>
</tr>
<tr>
<td>Shevari</td>
<td>50.39</td>
<td>16.88</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>465.07</td>
<td>131.89</td>
<td>13.49</td>
<td>10.22</td>
</tr>
<tr>
<td>3. Jowar</td>
<td>248.41</td>
<td>68.56</td>
<td>5.14</td>
<td></td>
</tr>
<tr>
<td>Cowpea</td>
<td>71.43</td>
<td>13.64</td>
<td>2.11</td>
<td></td>
</tr>
<tr>
<td>Subabool</td>
<td>48.81</td>
<td>15.37</td>
<td>3.07</td>
<td></td>
</tr>
<tr>
<td>Shevari</td>
<td>53.96</td>
<td>18.07</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>422.61</td>
<td>115.64</td>
<td>13.21</td>
<td>11.42</td>
</tr>
</tbody>
</table>

(149)
<table>
<thead>
<tr>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Cowpea</td>
<td>256.35</td>
<td>48.96</td>
<td>7.58</td>
<td></td>
</tr>
<tr>
<td>Subabool</td>
<td>59.12</td>
<td>18.62</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td><em>Shevari</em></td>
<td>66.27</td>
<td>22.20</td>
<td>3.55</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>381.39</td>
<td>89.78</td>
<td>14.85</td>
<td>16.54</td>
</tr>
<tr>
<td>5. Jowar alone</td>
<td>89.41</td>
<td>82.36</td>
<td>6.18</td>
<td>7.50</td>
</tr>
<tr>
<td>6. Jowar</td>
<td>280.16</td>
<td>77.32</td>
<td>5.79</td>
<td></td>
</tr>
<tr>
<td>+ Cowpea</td>
<td>65.08</td>
<td>12.43</td>
<td>1.92</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>345.24</td>
<td>89.75</td>
<td>7.71</td>
<td>8.59</td>
</tr>
<tr>
<td>7. Cowpea</td>
<td>246.03</td>
<td>46.99</td>
<td>7.28</td>
<td>15.50</td>
</tr>
</tbody>
</table>

**C. D. At 5% = 41.04 11.40**

It is evident from the table–26 that the system comprising of jowar with subabool and *shevari* (S–3) resulted in highest fodder production. Introduction of tree components in different conventional systems played a vital role in significantly increasing the green fodder and crude protein yield.

6.2. Development of Agro-silvi-forage production system in relation to conventional system under irrigated conditions.

(D. S. Chauhan)

Under irrigated conditions four improved and three conventional system of forage production were tried.

The data on fodder production (green and dry) and crude protein content are presented in table–27.
Tab'e-27 Fodder yield and protein content in different Agro-silvi-production systems under irrigated conditions:

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Green fodder (q/ha)</th>
<th>Dry matter (q/ha)</th>
<th>Crude protein production (q/ha)</th>
<th>Crude protein content in herbage mixtures (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2.</td>
<td>3.</td>
<td>4.</td>
<td>5.</td>
</tr>
<tr>
<td>1. <em>Cenchrus</em></td>
<td>175.38</td>
<td>54.36</td>
<td>4.07</td>
<td></td>
</tr>
<tr>
<td><em>Stylo</em></td>
<td>103.16</td>
<td>19.60</td>
<td>3.17</td>
<td></td>
</tr>
<tr>
<td><em>Subabool</em></td>
<td>59.90</td>
<td>17.25</td>
<td>3.53</td>
<td></td>
</tr>
<tr>
<td><em>Shevari</em></td>
<td>92.86</td>
<td>28.04</td>
<td>4.51</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>431.30</td>
<td>119.25</td>
<td>15.28</td>
<td>12.81</td>
</tr>
<tr>
<td>2. <em>Jowar</em></td>
<td>1626.31</td>
<td>414.70</td>
<td>31.51</td>
<td></td>
</tr>
<tr>
<td><em>Oat</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1626.31</td>
<td>414.70</td>
<td>31.51</td>
<td>7.59</td>
</tr>
<tr>
<td>3. <em>Jowar</em></td>
<td>747.87</td>
<td>241.70</td>
<td>18.37</td>
<td></td>
</tr>
<tr>
<td>+ <em>Cowpea</em></td>
<td>192.78</td>
<td>32.77</td>
<td>5.17</td>
<td></td>
</tr>
<tr>
<td><em>Oat</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>+ <em>Berseem</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1140.65</td>
<td>274.47</td>
<td>23.54</td>
<td>8.57</td>
</tr>
<tr>
<td>4. <em>Cowpea</em></td>
<td>572.39</td>
<td>97.30</td>
<td>15.37</td>
<td></td>
</tr>
<tr>
<td><em>Berseem</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>572.39</td>
<td>97.30</td>
<td>15.37</td>
<td>15.80</td>
</tr>
<tr>
<td>5. <em>Jowar</em></td>
<td>1534.79</td>
<td>391.37</td>
<td>29.74</td>
<td></td>
</tr>
<tr>
<td><em>Oat</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><em>Subabool</em></td>
<td>54.68</td>
<td>15.74</td>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td><em>Shevari</em></td>
<td>50.32</td>
<td>15.09</td>
<td>2.42</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1639.79</td>
<td>422.2</td>
<td>35.38</td>
<td>4.37</td>
</tr>
</tbody>
</table>

(151)
<table>
<thead>
<tr>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Jowar (K)</td>
<td>1284.47</td>
<td>369.92</td>
<td>28.11</td>
</tr>
<tr>
<td></td>
<td>+ Cowpea (K)</td>
<td>206.67</td>
<td>35.13</td>
<td>5.55</td>
</tr>
<tr>
<td></td>
<td>+ Oat (R)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>+ Berseem (R)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Subabool</td>
<td>51.66</td>
<td>14.87</td>
<td>3.05</td>
</tr>
<tr>
<td></td>
<td>Shevari</td>
<td>53.33</td>
<td>16.10</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1596.13</td>
<td>436.02</td>
<td>39.30</td>
</tr>
<tr>
<td>7.</td>
<td>Cowpea (K)</td>
<td>445.64</td>
<td>75.75</td>
<td>11.96</td>
</tr>
<tr>
<td></td>
<td>Berseem (R)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Subabool</td>
<td>58.81</td>
<td>16.93</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>Shevari</td>
<td>55.31</td>
<td>16.70</td>
<td>2.68</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>559.76</td>
<td>109.38</td>
<td>18.11</td>
</tr>
<tr>
<td></td>
<td>C. D. at 5%</td>
<td>68.45</td>
<td>17.26</td>
<td>16.55</td>
</tr>
</tbody>
</table>

K=Kharif sowing.  R=Rabi sowing.

The system, comprising of jowar in kharif and oat in rabi followed by introduction of Subabool and Shevari at an alternate row spacing of 1.5 metre from each other (S-S), resulted in highest production of green and dry fodder production. Crude protein content was found to be maximum in system No. S-6 i.e., jowar+cowpea in kharif and Oat+berseem in rabi along with tree components in both the seasons. *Sesbania sesban* (Shevari) can not persist for a long period under frequent defoliation. It may be concluded that *Sesbania sesban* is neither suitable for intercropping with perennial grasses nor with seasonal crops. Whereas subabool is the most suitable tree component for long term programme of forage production under irrigated conditions.

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DIVISION OF SEED TECHNOLOGY

SPR-2 : INVESTIGATIONS ON AGRONOMIC AND PHYSIOLOGICAL ASPECTS IN FORAGE SEED PRODUCTION.

2.1 Maximization of seed production in pasture and forage plants with the amelioration of agronomic practices of cultivation.

(R. P. Singh, G. K. Dwivedi & N. C. Sinha)

Effect of foliar application of phosphorus and potash on seed yield of berseem

A field experiment was conducted to examine the effect of foliar application of phosphorus (single super phosphate) and potash (KNO₃) over basal application of phosphorus (0, 60 and 80 kg P₂O₅/ha) on seed yield of Berseem. The treatments consisted of 12 combinations, 3 levels of basal application of P₂O₅ (0, 60 and 80 kg P₂O₅/ha), 2 levels of foliar application each of P₂O₅ 2.0 and 2.5 kg/ha through single superphosphate and potassium (1.5 and 2.0 kg KNO₃/ha) alongwith seven individual treatments.

Results indicated that basal application of 60 kg P₂O₅/ha, foliar application of 2.5 kg super phosphate and 2.0 KNO₃/ha individually increased the seed yield. Maximum increase in seed yield (1.2 q/ha) was noted when all these fertilizers were applied to the crop. Such increase in the seed yield was mainly due to either increase in number of balls/plants or number and weight of seed/plant. It can be derived from the data on seed yield component that foliar application of phosphorus increased the number of balls and seed/plant, while seed weight was increased when potassium was applied in addition to foliar application of phosphorus to berseem crop.

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2.2 Agronomic investigations for increasing seed yield in grasses.

(G. K. Dwivedi and R. P. Singh)

1. Studies on seed production potential of *Panicum* species as influenced by N fertilization.

Experiment was continued during the third year with three varieties of *Panicum maximum* (*Gatton*, *Trichoglume* and *chloratum*) and four levels of nitrogen (0, 40, 80 and 120 kg N/ha) to work out seed production efficiency of varieties and their response to levels of nitrogen. The results showed that var. *Gatton* produced the maximum seed yield (27.06 kg/ha) followed by the varieties *Trichogume* and *Coloratum*. The maximum seed yield (25.94 kg/ha) with 120 kg N/ha was at par with that obtained with 80 kg N/ha (25.0 kg/ha). The maximum seed yield was obtained in the first year followed by second and third years in all the varieties. Variety *Gatton* was found to be the most efficient in seed production and 80 kg N/ha was worked out as economical dose.

2. Effect of N and P on seed production of *Pennisetum polystachyon*.

The experiment was repeated in the third year with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and three levels of phosphorus (0, 30, and 60 kg P₂O₅/ha) to study the response to N and P nutrition. The results showed linear response to increasing levels of nitrogen. Maximum seed yield (259.48 kg/ha) was obtained with the application of 120 kg N/ha. The response to the application of phosphorus was significant only up to 30 kg P₂O₅/ha.

3. Effect of inter and intra-row spacing on seed production in grasses.

(i) *Setaria sphacelata* cv. nandi

(ii) *Chrysopogon fulvus*  
   (a) cv. Mhow
   (b) cv. Chandigarh

(i) *Setaria sphacelata* cv. nandi : An experiment on *Setaria sphacelata* cv. nandi was continued during the second year. The treatments consisted of 10 combinations of inter and
intra row spacings (75 cm × 75 cm, 75 cm × 50 cm, 75 cm × 30 cm, 75 cm × 15 cm, 50 cm × 50 cm, 50 cm × 30 cm, 50 cm × 15 cm, 30 cm × 30 cm, 30 cm × 15 cm, 15 cm × 15 cm).

Results revealed that the higher seed yields (50 to 57.10 kg/ha) were obtained with spacings of 50 cm × 30 cm and 50 cm × 50 cm. Narrow spacing of 15 cm × 15 cm produced the minimum seed yield (24.90 kg/ha).

(ii) \( \text{(a)} \) Chrysopogon fulus cv. Mhow: Nitrogen at 40 kg/ha in the form of urea was applied in the middle of July after inter-cultivation in previous year grass stand. Seed collections was completed on 10-10-1985.

The results showed the maximum seed yield of 44.63 kg/ha with a spacing of 50 cm × 50 cm followed by 39.83 kg/ha with 50 cm × 30 cm spacing. The maximum seed yield of 20.07 kg/ha was attained with a spacing of 15 cm × 15 cm.

\( \text{(b)} \) Chrysopogon fulus cv. Chandigarh: The experiment continued during the year under report and seed collection was completed on 30-9-85. The results revealed the maximum seed yield of 58.13 kg/ha in 50 cm × 50 cm spacing followed by 50.90 kg/ha in 50 cm × 30 cm spacing. Narrow spacing of 15 cm × 15 cm produced the minimum seed yield of 24.23 kg/ha.

The above findings suggest that 50 cm × 50 cm spacing is optimum for obtaining the maximum seed yields in Chrysopogon fulus and Setaria sphacelata grasses.

4. Effect of spacing and seed rates on seed production in grasses.

\( \text{(i)} \) Setaria sphacelata cv. nandi

The experiment with three row-row spacing (25, 50 and 75 cm) and five seed rates (2.5, 5.0, 7.5, 10.0 and 12.5 kg/ha) continued in the established sward. Application of 40 kg N/ha in the form of urea was made in the middle of July after weeding and interculture operations. The crop was harvested on 1-11-85 after seed picking.

The maximum seed yield of 45.31 kg/ha was obtained in the spacing of 50 cm followed by 39.64 kg/ha and 29.03 kg/ha in the spacings of 25 cm and 75 cm, respectively. The maximum seed yield of 44.97 kg/ha was obtained with a seed rate of 7.5 kg/ha followed by 5.0 kg/ha (40.54 kg/ha).

The above finding suggested the optimum row-row spacing of 50 cm and a seed rate of 7.5 kg/ha for maximum seed production.
5. Evaluation of *Cenchrus ciliaris* cultivars for their seed production efficiency.

A field experiment was laid out to evaluate ten varieties of *Cenchrus ciliaris* (Pusa Giant, Mo'apo, Jodhpur S-358, S-357, IGFRI S-3108, S-303, IGFRI S-3132, IGFRI S-59-1, Jodhpur local and hybrid) for their seed production potentialities. Six weeks old seedlings were transplanted in the middle of July after application of basal dose of 20 kg P₂O₅/ha in the form of SSP. The experiment was conducted in randomized block design with three replications. Nitrogen at 20 kg/ha in the form of urea was applied after one month. The seed collection was completed on 15th December 1985.

The maximum seed yield of 36.81 kg/ha was obtained in S-303 followed by 33.37 kg/ha in IGFRI S-3108 and Jodhpur S-358, respectively. Minimum seed yield was produced in IGFRI S-59-1.

2.3 Agronomical studies for exploiting system based seed production in forage crops (cultivated).

(R. K. Pandey)

1. Selection of oats genotype in relation to fodder cutting for seed based fodder-seed production.

In earlier studies of oat, IGFRI-3021 has been found most promising for seed production with 40 days fodder cut. This approach provided fodder in early part of the season without reducing seed yield. Therefore, this cultivar alongwith two more strains of oat, UPO-210 and UPO-136 were evaluated in relation to different cutting treatments (no cut, a cut at 40 days and a cut at 60 days crop stage). After fodder cut, the crop was left for seed production. The purpose of the study was to select better crop variety for higher fodder and seed production. The crop was supplied with 80 kg N (60 kg basal + 20 kg at 40 days crop stage) and 50 kg P₂O₅/ha as basal.

As compared to uncut oat IGFRI-3021, none of the treatment combinations appeared significantly different in seed yield. Both from fodder and seed production point of view, variety IGFRI-3021 with 60 days cut was found to be promising which provided an additional green fodder yield of 115 q/ha in the mid of the season and seed yield was not reduced under the system. With the same cut, oat UPO-210 yielded more fodder but its seed yield was reduced by 5.2 q/ha. The 60 days cut treatment yielded substantially more
fodder over 40 days, but its seed yield declined as compared to uncut control. There was no significant difference among the varieties.

2. Evaluation of mixed cropping systems of sorghum and cowpea for improved fodder-seed production system.

This was the final year of the study in which eight treatments were tried. Amongst the crop combinations, 50 cm apart row crop of seed sorghum, cv. M. P. Chari was introduced with cowpea, cv. HFC-42-1 both by broadcast and line sowing methods. In broadcasting, cowpea was sown @ 10 and 20 kg seed/ha and was immediately superimposed by line sown sorghum. In case of line introduction, two treatments were evaluated where @ 20 kg seed/ha with one row of cowpea was grown in the inter-row-spaces of seed sorghum. In one case, cowpea was harvested for fodder in the mid of the season, while in the other, it was maintained for seed production. The pure culture crops of seed sorghum and seed cowpea were also maintained at 25 and 50 cm row spacing. In closer spacing, 50 and 40 kg seed/ha were used for cereal and legume, respectively which reduced to their halves in wider ones. The objective was to work out the compatibility of cowpea with seed sorghum for the additional return. Treatments were tried in randomised block design replicated three times. Crop was applied with 40 P_2O_5 (basal) + 80 kg N (50 kg basal + 30 kg top dressing)/ha and sown in the second week of July.

As a result of cowpea introduction, there was no reduction in the seed yield of sorghum, cv. M. P. Chari, when compared to its pure culture crop. Both the treatments of broadcast and line introduction of cowpea @ 20 kg seed/ha produced additional yield of 3.2 to 3.3 q/ha. These treatments appeared to be promising as the total seed yield (13 q/ha) with associative cropping was more than the mean yield of cowpea and M.P. Chari grown as pure (8.7 q/ha) at 50 cm spacing. Similarly, an additional legume fodder (83 q/ha green) was harvested when cowpea combined with the seed sorghum in alternate rows. These results were in conformity with the findings of the previous year.

2.4. Studies on phosphorus and boron in cowpea, berseem and lucerne seed crops.

(S. M. Mishra)

1. Effect of increasing levels of P on yielding parameters and P concentration in different plant parts of cowpea at reproductive stage.
The effect of five levels of P (0, 20, 40, 60 and 80 kg P$_2$O$_5$/ha) on dry matter accumulation, leaf stem ratio, number of pods per plant, number of grains per plant, 1000 seed weight and seed yield per plant of cowpea was studied. P concentration in flower, leaf lamina, pods, grain and husk and its relation with seed yield was worked out. Application of 40 kg P$_2$O$_5$/ha increased the dry matter, leaf : stem ratio, number of pods and test weight (1000 seed weight), which appeared to be the determining factors for increased seed yield per plant without affecting the number of seeds/pod indicating a strong genotypic character. Higher level of P (80 kg P$_2$O$_5$/ha) adversely affected the plant characters responsible for higher yield. Although, increasing levels of phosphorus increased its concentration in different plant parts but the increased P uptake at levels above 40 kg P$_2$O$_5$/ha was not utilised for metabolic processes. Higher concentration of P in seeds as compared to other plant parts at harvest indicates its translocation to seeds from vegetative organs during seed formation and ripening stages.

2. Effects of P application on seed yield parameters, phosphorus, protein, sulphur and water soluble sugars in lucerne (*Medicago sativa L*).

A field experiment with five levels of P (0, 30, 90 and 120 kg P$_2$O$_5$/ha) was conducted on red soil to study the response of lucerne in terms of, number of tillers, number of flowers, number of seed per plant and seed weight per plant, mineral content (protein, phosphorus and sulphur) and water soluble sugars in flowers. The result revealed that P application increased the number of tillers, number and weight of flowers per plant—a prerequisite for higher seed yields. P application above 60 kg P$_2$O$_5$/ha was not found effective in increasing the dry matter accumulation or seed yields. Water soluble sugars in flowers increased with increasing P levels. Application of P increased its concentration in plant parts in all the cuttings but decreased the sulphur and protein contents. The effect of phosphorus on nutrient concentration was however, more pronounced in 3rd cutting as compared to 1st or second cutting.

2.5. Growth and physio-chemical analysis and their manipulation for increasing forage seed production.

(N. C. Sinha)

1. Effect of seed pre-sowing hardening on physiological behaviour and seed yield of Berseem (*Trifolium alexandrinum L.*)
A field experiment was conducted in red soils of Bundelkhand region. Seeds were subjected to following treatments:

(a) Seed soaked in tap water for 24 hours and dried at room temperature until they regained their original weight.

(b) Seeds soaked in tap water for 36 hours and dried as at ‘a’

(c) Soaking the seeds in tap water for 24 hours and seedling immediately without drying

(d) Soaking the seeds in tap water for 36 hours and method adopted as at ‘c’

(e) Control (untreated). This was undertaken to judge the effect of drying at two soil depth (5 and 3 cm) on the percentage of emergence, physiological behaviour and mineral composition and seed yield components.

The seeds were sown at two soil depth (5 and 3 cm). Results demonstrated that augmented effect of seed hardening on seedling emergence and physiological process responsible for seed yield was recorded in descending order of seed hardening (24 hours soaking), non harden seeds (24 hours soaking), harden seeds (36 hours soaking). Non hardening of seeds for 36 hours soaking adversely affect the plant growth due to leaching of sugar during excess soaking—an element for reduced seed vigour. Seed hardening developed the strength for seedling emergence as a result of efficient catabolic process, releasing high water soluble sugars needed for quick germination. This process also augmented the absorption of mineral nutrients (phosphorus, nitrogen and to some extent calcium) at bloom stage indicating a high metabolic activity during this period. Performance of seed hardening was effective at 5 cm deep sowing.

2. Physiological variability in Barley

A field experiment was conducted on red soils to study the physiological variability in 19 barley varieties on the basis of existing variability. Dwarf DL-120, DL-157 DL-70, 171, semi dwarf DL-200, DL-192, DL-245, DL-219 DL-254, early duration tall DL-63, DL-100, DL-207, DL-88 and late duration tall DL-263, DL-85 dwarf and DL-3, Ratna and DL-83. Results demonstrated that in barley varieties, high P : R (photosynthesis : respiration 3.08< 5.0) with moderate dark respiration rate, high harvest index, narrow leaf angle, size of ears, number of grains/ear showed close relationship with grain yield.
Among early duration varieties, DL-36-tall, and DL-120-dwarf were characterised by higher number of grains/ear, greater photosynthetic efficiency and higher number of grains, whereas DL-260 among semi-dwarfs was characterised by higher number and bidder size of grains.

The study revealed that the size of ear was more important in tall varieties whereas the number of grains/ear and number of ears/plant formed the important parameters in early dwarf and semi-dwarf varieties, respectively. The highest grain and fodder yield/plant was recorded in tall early duration variety DL-36, which had moderate harvest index of 0.43.

3. Varietal variability with regard to mineral composition of lucerne and their association with seed yield.

Variability with regard to mineral composition of seven lucerne varieties (Anand-2, Composite-2, T-9, Ahmad, Composite-5, SS-627 and Composite-1) was studied. Variety SS-627 was superior in respect of protein N and P contents of the plant. High seed yielding varieties (SS-627 and Composite-1) contained medium level of magnesium and low level of sulfur at last stage of crop growth.

On an average, phosphorus and sulphur contents declined sharply with cutting stage while magnesium showed less drop. The trend of protein and calcium was different than other nutrients. Protein N increased upto second cutting and then declined. Thus high nitrogen and phosphorus contents with moderate magnesium status at pan-anthesis appeared to have significance in building up of an efficient photosynthate and potential seed yield in lucerne crop.

4. Varietal variability and association of synthate formulation with yield components and dry matter production.

A field experiment was conducted in red soil to evaluate the relationship of synthate formation with yield components and dry matter production in six varieties of fodder sorghum (M. P. Chari, HD-2, PC-23, 2887-2, 3225-1 and 3197-1). Medium height group (HD-2) produced leaf and stem dry matter in such a way that it developed greater stem strength (180.8 mg/cm of shoot length) as compared to other varieties. Varieties 3225-1 had good leaf area (315 cm²) leaf width (5.0 cm) and shorter upper internodes and produced higher grain yield. Though the grain number was almost the same in varieties HD-2 and 3225-1, but grain yield (g/plant) was high in HD-2 as compared to 3225-1 indicating better development of sink in former variety.
Sugar concentration was high at anthesis and declined sharply during post anthesis period. Among the plant parts, stem showed highest value than cob and leaf indicating thereby that stem functions as reservoir. Sharp decline in sugar content of leaf and stem from anthesis to post anthesis period, indicated rapid translocation of sugar from these organs. Heavy unloading of sugar from leaves during the period adversely affected the plants to function photosynthetically. Accumulation of sugar in stem at anthesis and its efficient translocation towards sink at post anthesis stage indicates the seed production potential of sorghum and this was more so with HD-2 and 3225-1. An increasing sugar content of collar region of these varieties from anthesis to post anthesis period indicated that major amount of sugar from leaf and stem is being translocated downwards. This also shows that the utilisation of sugar was faster than translocation. Varieties HD-2 and 3225-1 had higher amount of sugar in stem at post anthesis stage indicating their forage value even after reaping the seed from the plants. Thus it may be concluded that greater leaf width and low translocation distance favour the synthesis of sugar and its accumulation in reproductive organ. There is further scope to increase the seed yield of the varieties HD-2, 3225-1 and M. P. Chari by augmenting the utilization efficiency and translocation rate of sugar in cob development.

5. Foliar application of KNO₃ and single super phosphate on the seed yield and sugar content of cowpea (*Vigna unguiculata* L.) var. HFC 42-1.

A field experiment was conducted in red soil to analyse the influence of foliar application of KNO₃ (1.5, 2.5 and 2.5 kg/ha) and single phosphate (1.0, 1.5 and 2.0 kg/ha) individually as well as in combination on water soluble sugar and seed yield components of cowpea var. HFC 42-1. The crop received 80 kg P₂O₅/ha through single super phosphate as basal dressing at the time of sowing.

Critical perusal of the data on seed yield components as influenced by foliar application of nutrients revealed that 2.0 kg/ha KNO₃ along with 1.0 kg/ha superphosphate at pre-anthesis stage increased the pod formation/retention capacity and seed weight. This inturn brought out an increase of 25.6% reaping value of cowpea.

Increasing concentration of KNO₃ increased the translocation of sugar from photosynthesize forming organs (leaf and stem) to reproductive organs and reduced the degeneration process of nodules by providing nitrogen and sugar to plant roots. Such findings emerged out from higher values of sugar in flower and roots at 2.0 kg KNO₃/ha as compared to
control which declined sharply at grain development stage. Lower concentration of super-phosphate (water spray) (1.0 kg/ha) increased the water soluble sugar in pedicel (2.5%), besides increasing the sugar concentration in flower (21.6%). The sugar concentration in flower declined rapidly at grain development stage without affecting the sugar concentration in pedicel (2.04%) as compared to control (1.65 to 0.95) indicating that phosphorus nutrition increased the retention capacity of pod bearing nodes during development period. Poor response to high dose of super phosphate on sugar concentration of various plant parts indicated that the major portion of P requirement was met by soil P. Thus the findings lead to conclude that potassium nitrate plays an important role in translocation and utilization of sugar in reproductive organs and reduces the degeneration of root nodules while phosphorus develops the retention power of pod besides enhancing the synthetic mechanism during anthesis to grain development phase. Thus a suitable dose of superphosphate (10 kg/ha) and KNO₃ (2.0 kg/ha) is must to reap high economic yield of forage variety of cowpea (HFC 42-1).

SPR-3 : INSECT FEST PATHOGEN INFLUENCES AND THEIR CONTROL IN FORAGE SEED PRODUCTION.

3.1. Toxicological studies in relation to insect pests of fodder crops.

1. Promising insecticides for insect pests of fodder mustard.

An experiment was conducted to study the comparative performance of three insecticides each at three levels viz. monocrotophos 36 EC (0.025, 0.05, 0.075%), rogar 30 EC (0.1, 0.15, 0.2%) and BPMC 50 EC (0.1, 0.15, 0.2%) sprayed at 30 and 75 days of crop growth. First spray was aimed against Athalia lugens king and 2nd spray against Lipaphis erysimi kalt. Observations on sawfly and aphid incidence were recorded just before and after the 1st spray (sawfly larvae/m²) and the 2nd spray (aphids/5 plants) at weekly intervals. Mustard sawfly population dwindled and disappeared after 20–25 days with 1st spray and then aphid population started building. The crop was cut (2 lines/plot of 6 lines) at 50% flowering stage for fodder purpose and the seed yields were recorded from the remaining rows.

Insect pest incidence:

Monocrotophos at all the levels was found to be the best insecticide in arresting the sawfly population (1.11 to 3.11 larvae/m²) and aphids (172 to 257 aphids/5 plants). Larger populations of sawfly 1.33 to 3.20 were recorded from the plots treated with rogar larvae/m² and aphid (226 to 348/5 plants) and BPMC (1.78 to 4.30 sawfly larvae/m²).
and 308 to 416 aphids/5 plants). All the treatments gave effective control of both the pests as compared to control plot with maximum pest population (7.55 sawfly larvae/n.² and 2276 aphids/5 plants).

Green fodder/seed yields:

Monocrotophos treated plots gave highest green forage (205 to 262 q/ha) and seed yield (6.74 to 10.82 q/ha). It was followed by rogar which resulted in the green fodder yield of 189 to 254 q/ha and seed yield of 5.48 to 9.88 q/ha. BPMC was comparatively less effective (192 to 274 q/ha green matter and 6.22 to 8.70 q/ha seed yield). The corresponding yields in the check plots were 146 and 3.6 q/ha. It was concluded that insecticidal spray at 30 and 75 days of crop growth was quite beneficial and that monocrotophos at 0.075% was the best treatment.

2. Residues of phorate and endosulfan on M. P. Chari.

The experiment conducted during summer 1984 was repeated. M. P. Chari was grown on soil treated with phorate 10 G @ 1.5 kg a. i./ha and endosulfan 35 EC was sprayed at 0.07 and 0.1% on 40 and 60 days old crop. Plant samples were collected, extracted and analysed spectrophotometrically to determine insecticidal persistence.

Table: 28 Residues of phorate 10 G on M. P. Chari grown on soil treated @ 1.5 kg a. i./ha.

<table>
<thead>
<tr>
<th>Stage of crop growth (days)</th>
<th>Residues (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>7.08</td>
</tr>
<tr>
<td>21</td>
<td>5.25</td>
</tr>
<tr>
<td>35</td>
<td>2.81</td>
</tr>
<tr>
<td>45</td>
<td>0.39</td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

(163)
Results (table 28) indicated that phorate applied to soil as 10% granules at the time of sowing got absorbed into the plant system and persisted a little over 45 days after treatment. In case of endosulfan (Table 29) the insecticidal residues persisted up to 14 days and 21 days when applied at 0.07 and 0.1 per cent, respectively. It appeared that, dissipation from lower was faster than from the higher dose.

Table 29: Endosulfan residues on M. P. Chari from double spraying (after 40 and 60 days of sowing).

<table>
<thead>
<tr>
<th>Days after treatment</th>
<th>Residue (ppm) 0.07%</th>
<th>Dissipation (%) 0.07%</th>
<th>Residue (ppm) 0.1%</th>
<th>Dissipation (%) 0.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.02</td>
<td>--</td>
<td>6.88</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>3.06</td>
<td>39.04</td>
<td>5.16</td>
<td>24.4</td>
</tr>
<tr>
<td>7</td>
<td>1.38</td>
<td>72.51</td>
<td>3.11</td>
<td>54.8</td>
</tr>
<tr>
<td>14</td>
<td>0.04</td>
<td>99.20</td>
<td>1.12</td>
<td>83.70</td>
</tr>
<tr>
<td>21</td>
<td>--</td>
<td>100.00</td>
<td>0.22</td>
<td>97.80</td>
</tr>
<tr>
<td>30</td>
<td>--</td>
<td>--</td>
<td>BDL</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Endosulfan 0.07% 14th day was much below the tolerance level of 2 ppm (FAO/WHO 1974). At 0.1% it was nearly equal to its tolerance level on 21st day, whereas cent per cent dissipation from these doses was recorded on 21st day and 30th day of spray respectively.

It was, thus, conducted that the crop can safely be harvested as fodder at 70 days in case of phorate (@ 1.5 kg a, i./ha) and endosulfan 0.075% treatments. But it would be safe only a few 80 days of sowing for fodder when treated with the higher dose of endosulfan i.e. 0.1 per cent.
3.2 Seed-borne diseases and their control in forage crops.

(S. N. Singh)

1. Isolation and identification of different micro-organisms associated with forage crops.

The main pathogens were found to be associated with seed of sunflower, sesame and safflower. Some of these fungi like *Macrophomina phaseolina*, *Fusarium Oxysporum* and *sclerotium rolfsii* were more frequent seed-borne pathogens causing diseases like collar rot, wilt and necrotic ring around the collar region.

Seed mycoflora in the cultivars of *stylosanthes* was detected. The extent of anthracnose disease caused by the pathogen *Colletotrichum gloeosporioides* was assessed in *stylosanthes hamata*, *S. humilis*, *S. scabra*, *S. gracilis* to 33.33 in *S. scabra* by the blotter method and 8.55% to 18.5% by growing on test method, respectively.

Other prevalent pathogens were *Fusarium moniliforme* and *curcularis lunata* which reduced the seedling emergence up to 28.6%.

The incidence of the seed-borne pathogens appeared to be inversely correlated with the seed germination either in healthy or diseased seeds.

2. Evaluation of fungicides for controlling seed-borne diseases.

Seedling diseases: A wilt symptom in *sesbania*, guar and castor was detected from these plants. The prevalent and virulent pathogen *Sclerotium rolfsii* was identified as a causal organism which infects these hosts in the collar region and its pathogenicity was established.

Amongst different seed treatments, Bavistin and Thiram @ 0.3% were proved to be the promising fungicides for the control of this pathogen on the basis of *in vitro* test.

Seed production trial (*In Vivo*):

(a) Berseem (IGFRI-S-98-1):

A pre-sowing seed treatment with Bavistin, Thiram and Vitavax @ 3 gms/kg seed was done for the control of seed-borne pathogens viz. *Fusarium oxysporum*, *curcularia lunata* and *Aspergillus flavus*. Seeds were soaked in these fungicidal solutions separately for 24 hours and were hardened by drying at room temperature until they regain their

( 165 )
original weight. Likewise in another treatment, seeds were soaked for 24 hours but sown immediately without drying at two depths 3 cm and 5 cm in the field.

All the fungicides controlled the fungi associated with seeds by reducing the seedling mortality. Significant Thiram increased the emergence by 16.6 to 34.4 percent and reduced the seedling mortality by 13.5 to 24.8 percent both at 3/5 cm depths.

The treatments improved the growth parameters such as plant height, number of shoots, root length, nodulation and increased the green fodder yield by 50.80%. In Thiram and Bavistin treated plots, the incidence of collar rot and leafspot diseases were negligible, which in turn increase number of seeds/ball, 1000 seed weight as well as seed yield by 48-78%.

(b) Lucerne IGFRI-S-244:

In view of the similar problem like berseem, the same seed treatment experiment was conducted with lucerne crop. Pre-hardening soaking and drying was done to see their effect on germination, mortality and final population.

The fungicide Bavistine @ 3 gm/kg seed gave the best result by increasing emergence to an extent of 20-35% by sowing at 5 cm depth. The seedling mortality due to *Fusarium oxysporum*, *F. equisetic* and *Pythium* spp. was reduced by 15.4 to 26.7%. The incidence of pre-emergence damping off caused by *Phytophthora megasperma*, downy mildew (*Peronospora trifoliorum*) and rust (*Uromyces striatus*) were increased by 15-22% in non-treated plots during the 2nd and 3rd cutting.

It was found that the technique of soaking the seeds in 0.3% solution of Bavistin suspension, eradicated the seed-borne pathogens and increased the seedling vigour and emergence, well as increased the green fodder yield upto 60% by eliminating other plant.

(c) *Stylosanthes*—(for the control of anthracnose disease).

During the 2nd year of establishment, the incidence of *Colletotrichum gloeosporioides* was rated for disease severity in stem and leaves due to presence of elliptical lesions. Symptoms of disease were upto 11.28% in *S.Viscosa*, *S. gracilis* and *S. scabra* whereas it was 3-10% in *S. humilis* and *S. hamata*. The pre-sowing treatment Bavistin @ 0.3 gm/kg seed followed by spray was found to be quite effective in limiting the disease development followed by vitavax when the first lesions appeared.
(d) Sorghum (var. P. C.−1, S−171, S−307, S−260, JS−20 & S−263).

Among the fungicides a systemic fungicide Bavistin @, 0.3 gm/kg was found to be good for improving the final plant stand by increasing the emergence and reducing the seedling mortality due to seed-borne pathogens like Fusarium moniliforme, F. Semitectum, Curvularia lunata, Alternaria and Helminthosporium Spp.

It was found that fungicidal seed dressing with Bavistin increased the emergence to the extent of 15−25% while the effect of vitavax was marginal. The fungicide Bavistin checked these pathogens and other grain molds and increased the test weight and seed yield.

2. To devise suitable measure for maintenance of seed health during storage.

(A) Influence of seed treatment on storage and viability of seeds: Cowpea (IGFRI−S−143, 978, 457, 450 and 515)

Seeds stored in paper bags, cloth bags and polythene bags could not maintain their viability for long period. Seed treatment with Dithane Z−78 and Bavistin @ 0.25 gm/kg of seed at low moisture content of 8 per cent was more effective than those stored at 10 per cent moisture content.

The frequency of isolation of storage fungi revealed a definite pattern. The Macrophomina phaseolina were isolated in more frequencies in freshly treated seeds in 1st, 2nd and 3rd years of storage but it diminished during 4th 5th, years of storage. The occurrence of Fusarium moniliforme, F. Semitectum and Aspergillus flavus were present all through whereas Curvularia lunata were isolated in very less frequencies in long term storage.

The seeds treated with these fungicides were able to record higher germination (75%) up to 5 years, whereas in untreated seed it was negligible (8%) even in first year.

It would be advisable to treat the cowpea seed with Dithane Z−78 and Bavistin at 0.25 gm/kg of seed and pack at 1% moisture content in plastic airtight containers for storing up to 5 years.

II. Sunflower Seeds:

Thiram was found to be the best fungicide at 0.25 gm/kg of seed when pack at 7% moisture content in airtight plastic containers up to two seasons. It eliminates the storage fungi Fusarium oxysporum, P. Moniliforme, Alternaria spp, Rhizopus nigricans. The seeds treated with fungicides were able to give higher germination percentage in comparison to untreated seeds,
3.3 **Host parasite relationship in fodder crop seed production.**

(S. N. Singh)

1. Screening of Bajra germplasm against shoot fly and stem borer.

Nineteen bajra germplasm materials were sown for their tolerance against *Atherigon soccata* Rond and *Chilo partellus*, Swin shootfly incidence was recorded twice, i.e. 15 and 30 days after sowing, whereas stem borer incidence was recorded 40 and 60 days after sowing. The crop was cut at 50% flowering stage for green fodder.

It is evident from the results that five bajra germplasms V-61, V-824, V-821, V-63 and V-815 were relatively more tolerant to shoot fly (14.69 to 18.45%) damage than rest of the cultivars, whereas in case of stem borer, germplasm V-823 and all the five tolerant germplasm to shoot fly exhibited lowest degree of susceptibility. Thus, the germplasm may be categorised as:

I. **Tolerant**: V-61, V-824, V-821, V-63, V-815 and V-823

II. **Mediocre**: V-832, V-814, V-65, V-62, V-833, and V-826.

III. **Susceptible**: V-66, V-825, V-816, V-819, V-817, V-801 and V-64.
DIVISION OF PLANT ANIMAL RELATIONSHIP

PAR-1 : NUTRIENT LEVELS AND ANTIQUALITY FACTORS IN HERBAGES

1.1 Investigation to evaluate histochemical technique vis-a-vis other procedures.

(L. K. Karnani)

Samples of three grass species of Anjan grass viz., *Cenchrus setigerus* (pusa yellow anjan), *Cenchrus hydrid* and *Cenchrus ciliaris* (3108) were collected at C. R. Farm at monthly intervals from August to October.

Histochemical studies: The plant was divided into three parts viz., leaf blade, top stem and bottom stem. Thin sections of all the samples were cut, stained with acid phloroglucinol and chlorine-sulphite and examined under microscope at magnification of 40. In leaf blade, lignified tissues stained positive with acid phloroglucinol was observed in the xylem of the large vascular bundles, whereas the sclerenchyma stained positive with chlorine-sulphite. Unlignified tissues like the parenchyma surrounding the vascular bundles, which are separated by mesophyll were observed. In the stem, lignified tissues in the thick band of sclerenchyma in the epidermis, stained positive with acid-phloroglucinol. The parenchyma cell stained positive for lignin with chlorine-sulphite only after keeping for some time.

In another experiment, 5 mm long sections of the plant parts were cut. These sections were incubated for 72 hrs with buffer solution (pH-7.0) as control and with strained rumen liquor (SRL). The study revealed the types of tissues present in the plant parts and showed that all the cell's were intact in sections of all the plant part incubated with buffer for 72 hrs. In the leaf sections incubated with SRL, the mesophyll was completely degraded after 72 hrs of incubation. Parenchyma bundle sheath and epidermis remained partially degraded even after 72 hrs of incubation. Lignified tissues were not degraded at all. In stems, difference due to maturity was not clearly seen after 72 hrs of incubation. The epidermis, sclerenchyma band and the vascular bundles remained intact while the phloem and
the non lignified parenchyma cells were degraded in the top stem. However, in the bottom all the tissues appeared intact.

1.2 In vitro studies on the digestibility of important fodders and forage crops

(S. C. Gupta)

1. An investigation into IVTDMD versus IVTOMD values

During in vitro analysis, IVTDMD values can be misleading due varying ash content soil contamination of samples. A superior parameter for making better comparison of feeding value may thus be calculated either on O. M. (IVTOMD) or D.M. (IVTOMD) basis.

In the present study, differences between available IVTDMD and IVTOMD values of samples and their trends in different forages have been considered. It is followed by correlation studies between IVTDMD & IVTOMD or IVTOMD using 3 sets of data on forage oat. It was observed that IVTDMD values were higher than IVTOMD estimates in two samples of berseem (by 3.84% on average, ±1.61% SE), and in MP Chari (n=16.1, 53 ± 2.24%) and cowpea (n=20:1.35 ± 0.19%)—both on 50% flowering—used as standards in different in vitro experiments. However, in the case of 3 varieties of forage oat (Kent, Weston-11, and Algerian), the average differences in the two sets of values tended to increase from early boot (n=8: -1.14 ± 0.13%) to early anthesis (n=4: 0.05 ± 0.07%), milk (n=5: +0.60 ± 0.46%) and full maturity (n=9: 2.19 ± 0.30) in the 1st cut; as well as when regrowths were clipped after 44 to 47 days of previous cut at early boot (n=6: 0.31 ± 0.42), early anthesis (n=6: 0.62 ± 0.18) and milk (n=6: 1.03 ± 0.08) stages growth. Corresponding difference in 3rd cut in kent was 0.58 ± 0.67%. During studies on prediction of IVTOMD, it was observed that correlation coefficients of regression equations to predict IVTOMD using IVTDMD values in forage oat ranged from 0.989 to 0.998. Corresponding correlations to estimate IVTOMD values varied between 0.924 to 0.979. The above results show that IVTDMD values in forage oat may be as good as IVTOMD and relative assessment of its nutritive value may be possible from IVTDMD values.

1.3 (a) Ensilage of herbage and other crop residues

(A. P. Singh)

1. Studies on Hybrid napier, stylosanthes and sesbania silages
Silage was prepared from Hybrid napier NB-21 in laboratory and it was observed that the NDF, ADF and HC dropped considerably after ensiling. When Napier, *Stylosanthes* and *sesbania* were ensiled, soluble oxalate contents increased.

2. Studies on oat silage

Silage was prepared from wilted oat fodder (DM 50% or more). It was observed that wilting reduced buffering capacity from 46.00 to 22.8 m e./100 g D. M. and water soluble nitrogen from 0.992 to 0.672%. However, pH of the water extract prepared remained unchanged and reduced the rate of fermentation considerably. The flieg index of wilted silage was as high as 90 compared to 29 in unwilted silage indicative of superiority due to witing. The study suggests that high quality hay'age can be prepared from oat wilted to more than 50% DM content.

3. Quality of high moisture berseem and oat silages using mature grass bed as absorbent of effluent

While ensiling above fodder a bedding of dry grass was used in the bottom of the pit. The fermentation products in berseem and oat silages as well as their respective bedding materials of pit silage were similar to those of laboratory silages. However, water soluble nitrogen, ammonia-N greatly varied when concentration of these constituents were higher in pit silage on the basis of L%T value. Oat as well as its bedding material was graded as intermediary in stability and berseem as unstable silage. Grass bed of laboratory berseem silage was found to be intermediary while pit silage was unstable. There was 2-3 fold increase (2.68-8.52%) in CP and calcium (0.26-0.67%) content of the grass bed and most of the CP was in the form of water soluble nitrogen. Dry matter intake recorded for few days (4-7) indicated that the intake was low (1.64-1.68% B. W.) in oat silage, while it was higher (1.90-2.48% B. W.) for berseem silage.

1.3 (b) Influence of different additives/supplements in silage making

(A. B. Majumdar)

1. Studies on the additives for cowpea silage

Fodder cowpea at 50% flowering stage was harvested, chaffed and directly ensiled
with and without additives viz, formic acid, sulphuric acid and phosphoric acid in order to compare the effect of three additives. The chaffed unwilted material was uniformly mixed with 0.3% (fresh wt.) F-1, S-1, P-1, & 0.6% (fresh wt.) F-2, S-2, P-2 of above additives with control as without additives (c). Green cowpea at the time of ensiling contained 20.00% DM, 17.88% CP, 43.66% NDF, 34.24% ADF, 56.34. Cell content, 9.42 Cellulose & 10.82 total ash.

The silage was opened after 120 days of ensilment to see the fermentation changes and quality of silages. Fermentation pH, ammonia-N, lactic acid, acetic acid, butyric acid were determined and the quality was assessed on the basis of flieg index. All the silages except control appeared to be good. The control silage gave ammonical pungent smell. All the 0.6% acid treated silages possessed pleasant aroma except phosphoric acid treated silage which emanated mild smell. The biochemical data revealed that control silages as well as lower acid treated silages were moderately stable (L%T from 30 in control to 30 in F-1) while it was stable in case of silages treated with higher concentration of acid except P-2 which has L%T 42. Control silage was less stable than treated silages. Formic acid treated silages were better than other silages at all the levels of treatments. All the treatments depressed the acid fermentation remarkably when compared to control silage. The control silage had butyric acid 1.0% which adversely affected the silage quality (flieg-index 10). Formic acid was more effective in controlling the acetic acid and butyric acid production in both the cases. Phosphoric acid was found least effective in inhibiting the VFA productions. Protein breakdown as seen by ammonia nitrogen values (calculated as % of total N) was high in control silage (16.42) which was considerably checked by formic acid followed by sulphuric and phosphoric acids. Amongst the silages prepared F-2 produced “Excellent” and S-2 produced “Good” quality silage.

2. Quality and feeding value of “Pioneer” jowar silage

(A. B. Majumdar and V. S. Upadhyay)

Pioneer jowar at 100% flowering stage was harvested and wilted to about 40% dry matter. It was chaffed to 2-3 cm size and then ensiled in pucca pit. After 180 days the silo was opened for the assessment of its quality. The silage was fed ad lib to six growing male calves (body weight 122-141 kg) with supplementation of lucerne hay @ 1 kg/animal/day. The physical appearance of the silage was good. It possessed sweetish smell and good texture. As seen by the biochemical parameters (pH-4.29%, NH₃-N-0.056, lactic...
acid-6.87%, acetic acid-2.78%, butyric acid-0.03%, total acid 9.68%, L%T-71, NH₃ N%TN-6.24. The L%T value (71) shows the stability of silage as "very good" and the fleig-index (88) shows the quality of silage "excellent". Compared with the original material ensiled, there was 3.5% unit rise in NDF and ADF content while there has been no change in hemicellulose content. Decrease in cell content in the ensiled material showed that cell content was utilized by the micro-organism during fermentation. Dry matter intake was found to be $2.39 \pm 0.08$ kg/100 kg b. w. and DMD was $57.70 \pm 1.58\%$.

3. Studies on the quality and feeding value of maize silage:

(A. B. Majumdar and V. S. Upadhyay)

Maize var. "African tall" was harvested at dent stage, wilted for 24 hrs and ensiled in pucca pit. The silos were opened after 200 days of ensilement. The chemical composition of the original material was as follows: CP-9.82, NDF-65.83; ADF-45.28; hemicellulose 19.55 and CC-34.17.

The physical appearance of the silage was satisfactory, having brown colour and possessing mild peasant aroma. The biochemical characteristics of the silage were as follows: pH-4.8%, NH₃-0.125, TN-1.54%, lactic acid-3.64%, acetic acid-3.36%, butyric acid-0.12%, total acid-7.62, L%T-48.00, NH₃-N%TN-8.12. The silage based upon the physical characteristics and fleig-index (62) could be rated as good (L%T-48). The silage was fed ad lib with the supplementation of lucerne hay (DM-91, CP-20%) @ 1 kg./animal/day to six growing calves. The DMI and DMD were found to be $2.03 \pm 0.06$ kg/100 kg b. w. and $59.22 \pm 1.07\%$ which could be rated satisfactory. The silage was analysed for its fibre fractions (NDF-66.45, ADF-49.82, CC-33.55, HC-16.63). When compared with the original, there was marginal rise in NDF (0.5% unit) whereas, significant rise in ADF content (5% unit) and decrease in hemicellulose content (3% unit) which showed that a portion of hemicellulose was fermented by microbes during ensiling process.

PAR-2: NUTRITIONAL EVALUATION OF FORAGE AND FORAGE PRODUCTION SYSTEMS.

2.1. Investigation on effect of various chemical and physical attributes of forages on the intake as well as digestibility coefficients of various nutrients

(V. C. Pachauri)

1. Nutritional values of fodder production system of napier + stylo + sesbania.

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Studies on nutritive value of fodder production system \((\text{napier} + \text{stylo} + \text{sesbania})\) were carried out. The ratio of green fodder obtained was worked to be \(2 : 1 : 0.5\). Green fodder was chaffed and thoroughly mixed before feeding. Four growing calves of average live weight of 180.5 kg were selected and offered \textit{ad lib} green fodder. The preliminary feeding lasted for one month followed by a metabolism trial cum collection period of seven days. The stage of growth of napier was quite advanced as evidenced by high D. M. percent of mixed forage (46.2%). Chemical composition of the feed offered and F. residue have been presented in table—30. Perusal of the table—30 clearly shows that the fodder production system of \textit{napier}+\textit{stylo}+\textit{sesbania} supplies enough nutrients for growing calves.

Intake digestibility coefficients & nutritional value of the feed have presented in table —31. Intake of D. M. by the calves was quite good and indicative of high palatability of feed. The digestibility coefficients of the most of the nutrients ranged between 60%—75% except E E which was about 40%. This shows that intake as well as digestibility coefficient of the nutrients of \textit{Napier}+\textit{Stylo}+\textit{Sesbania} \((2 : 1 : 0.5)\) were of high order. The green forage supplied on D. M. basis 7% DCP and 57% TDN. Intake of DCP, TDN and D. E. (table 31) was also satisfactory. The study showed that the fodder production system of \textit{napier}+\textit{stylo}+\textit{sesbania} provides sufficient nutrients for growing calves and has good nutritional value.

Table—30 : Chemical composition (\%) of feed offered and feed refuse and digestibility coefficients (\%)

<table>
<thead>
<tr>
<th></th>
<th>Feed offered</th>
<th>Feed residue</th>
<th>Coefficient digestibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. M.</td>
<td>92.62</td>
<td>95.29</td>
<td>67.73</td>
</tr>
<tr>
<td>O. M.</td>
<td>84.80</td>
<td>84.87</td>
<td>66.97</td>
</tr>
<tr>
<td>Ash</td>
<td>15.20</td>
<td>15.13</td>
<td>—</td>
</tr>
<tr>
<td>C. P.</td>
<td>9.38</td>
<td>9.38</td>
<td>74.67</td>
</tr>
<tr>
<td>C. F.</td>
<td>33.35</td>
<td>33.17</td>
<td>61.89</td>
</tr>
<tr>
<td>E. E.</td>
<td>1.86</td>
<td>1.95</td>
<td>39.47</td>
</tr>
</tbody>
</table>

( 174 )
# Table 31: Nutrient intake of calves and nutritional value

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Net intake kg/day</th>
<th>Intake per Metabolic size g/kg W°0.75/day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nutrition intake:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>5.56</td>
<td>159.80</td>
</tr>
<tr>
<td>D. C. P.</td>
<td>0.390</td>
<td>7.91</td>
</tr>
<tr>
<td>TDN</td>
<td>3.17</td>
<td>64.40</td>
</tr>
<tr>
<td>DE Mcal/head/day</td>
<td>17.72</td>
<td>359.93</td>
</tr>
<tr>
<td><strong>Nutritional value:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. P. (%)</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>T. D. N. (%)</td>
<td>57.00</td>
<td></td>
</tr>
</tbody>
</table>

(175)
2.3. Evaluation of protein quality of forages and grasslands.

(P. Kumar)

1. Laboratory evaluation of protein protection of herbage using formaldehyde.

Samples of five legume forages viz., cowpea, stylo, desmanthus, Leucaena and berseem were collected (25 kg each) and converted to hay. The dried samples were powdered in the winny mill. Six replicate samples of 50 grams were weighed from each of the above five feeds and treated with formalin as detailed below:

(a) 0.75 g formaldehyde per 100 gram of herbage protein (0.75%)
(b) 1.0 g formaldehyde per 100 grams of herbage protein (1.00%).
(c) 1.25 g formaldehyde per 100 grams of herbage protein (1.25%).

After the stipulated period of preservation (10 days) samples were spread out in trays for few hours and then subjected to laboratory analysis for total nitrogen, water soluble nitrogen, and salt peptizable nitrogen. Simultaneously untreated forage sample were also analysed for the above parameters as control. The results of analysis have indicated that treatment (b) is satisfactory in terms of reduction of solubility and salt peptizability. There was no significant difference between treatment b & c therefore 1% formaldehyde (b) treatment was considered satisfactory.

Method of determination of true protein in forage has been standardized and efforts are under way to standardize method of in vitro protein digestibility using nylon bag.

2.4. Micro-nutrients in pastures and their utilization

(K. S. Ramachandra)

1. Polled hair mineral levels and histological studies in growing calves

The marginal deficiency is expressed generally through reduced growth rates and reproductive performance. Since clinical signs are not always manifested in such marginal
deficiencies it becomes difficult for detection of such border line cases. The chemical
analysis of feeds for the levels of trace minerals may not always be useful in determining
their adequacy or otherwise in the diets of the animals. Under field conditions the analysis
of polled hair mineral levels and hematological parameter often give useful information about
the overall status of the trace minerals in animals. A study was undertaken to determine
trace mineral levels of polled hair of growing trace calves, maintained on conventional forage
based feeding regime at the central farm of the Institute. The polled hair from the calves
were taken for analysis periodically. The minerals viz, copper, iron, zinc and manganese
were determined by Atomic Absorption Spectrophotometer.

The observations recorded revealed that the trace mineral content of polled hair
ranged from 3.12 to 8.91 ppm (5.29±1.62) for copper, 25.21 to 162.47 ppm (100.42±39.45)
for manganese and 44.52 to 96.56 ppm (67.52±16.59) for zinc. The results indicate a
deficiency of copper, manganese and zinc in the samples analysed. Concurrently hematolo­
gical studies were also conducted to determine the hemoglobin, P. C. V. blood zinc and
and copper levels in the growing calves. The hemoglobin values ranged from 8.6 to 14.5 mg/100
ml which are of the lower order in comparision to normal values. The P. C. V. values
ranged from 34.0 to 52.0%. The copper level in blood varied from 108 to 165 mg/100 ml
with majority of the samples having below normal values. The zinc content in blood was
110.0 to 148.0 mg/100 ml. The present study has indicated that there is a deficiency of
copper and zinc as indicated by the values of these minerals in the polled hair and the blood
serum.

2.5 Nutritional evaluation of forage legumes with special reference to *Sesbania aegyptica*

(A. Rekib)

1. Associative effect of graminaceous forages on chemical composition and *in vitro*
digestibility of low grade roughages (*in vitro* studies)

Low grade roughages fortified with *Sesbania aegyptica, Berseem, Leucaena leucocephala*
were analysed for CP, NDF, HC, Ash, Silica, IVTDMD and NDF digestibility. The
studies indicated that addition of *Sesbania* to roughage at 25, 50 and 75% levels improved
IVTDMD to 64.4, 69.3, 76.1 C. P. to 9.48, 14.01 and 18.51%. Addition of *leucanea* at the
same levels improved IVTDMD to 60.46, 66.27 & 75.57% and C. P. 7.84, 10.96 and 14.27%
and by cowpea IVTDMD to 60.6 and 72.0% and C. P. 7.98, 10.15 and 13.90% by berseem
IVTDMD 69.62, 71.57 and 78.81 and C. P. 7.64, 11.44, 15.27% respectively.

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Inclusion of legume forage at 25, 50 and 75% improved the CP content to 7.16, 11.11 and 15.17% respectively and *Sesbania* had an edge over other legumes. IVTDMD was improved to 68.76, 73.25 and 77.58% and it followed same trend as that of C. P.

3. Comparative performance of legume forages with special reference to *S. aegyptica* on the improvement of sorghum kadbi (*in vitro* studies)

Four legume forage i.e. *S. aegyptica*, *L. leucocephala*, cowpea and berseem were mixed with sorghum kadbi at 25, 50 and 75% levels. Fortification improved CP from 5.3 to 8.00%, 11.84 and 15.47% respectively. There was significant difference in the CP content of the forage mixtures and *S. aegyptica* had an edge over other legumes. IVTDMD values increased with increasing levels of legumes and berseem had an edge over other legumes.


Study was conducted to compare performance of various legumes for improving quality of dry mixed grasses. The legumes were added at 25, 50 and 75% levels. Addition of legumes improved CP from 5.36% to 8.50, 11.66 and 15.02%, *Sesbania* having an edge over others. IVTDMD was improved from 50.46 to 55.77, 64.33 and 72.70 respectively and there was significant difference of IVTDMD values amongst the mixture of different legumes and berseem grass mixture was considered to be best. It also had higher NDF digestibility.


Legume forages i.e. *Sesbania*, *Leucaena*, cowpea and berseem were added at 25, 50, 75% levels to wheat bhusa. CP content improved from 2.81 to 10.35 and 14.66% respectively, *Sesbania* at 75% level improved CP to maximum (18%). IVTDMD improved significantly due to addition of legumes and maximum increase was obtained with berseem. Cowpea and berseem scored over *Sesbania* and *Leucaena* in improving NDF digestibility.

6. Comparative performance of legume forage with special reference to *Sesbania* on the improvement of oat straw (*in vitro* study)

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Four legumes i.e. *Sesbania*, *Leucaena*, cowpea and berseem added to oat straw at 25, 50 and 75% levels. CP content significantly improved from 6.52 to 10.53 and 17.13%. Maximum CP was recorded with *Sesbania*. The lowest NDF content was obtained with *sesbania* and it was highest with cowpea. IVTDMD improved due to addition of legumes and the improvement was more with *Sesbania*.

7. Nutritional evaluation of *Stylo* species as influenced by phosphatic fertilizers.

(A Rekib and K. C. Kanodia)

Five species of *stylo* and two cultivars of *S. scabra* were grown with three phosphate levels i.e. 0, 40 and 80/ha (P-0, P-2 and P-3). The samples were taken in the month of September and February to study seasonal changes. In February cut, dry matter percent of P-0 was high in 3 *Stylo* species viz., *S. gracillis*, *S. viscose* and *S. scabra* (4C205), but low in *S. scabra* (40289). While in September, P-2 contained greater percent of dry matter. Average (%) values of CP, NDF, ADF, lignin, cellulose, hemicellulose, IVTDMD in sept and Feb. cuts were 12.56, 11.19, 54.14 & 43.66, 39.86 & 42.96, 7.88 & 11.34, 52.00 & 31.62; 14.27 & 10.70 and 72.68 and 59.08 respectively. Phosphorus applications did not influence most of the parameters.

3.1 Evaluation of cultivated fodder crops and pastures for growth in calves

(N. C. Verma)

1. Evaluation of *Cenchrus ciliaris* grass with and without *Stylosanthes hamata* for growing cross bred calves.

Eight cross-bred calves (55.112 kg live weight) were divided into two groups of four animals each and allowed to graze (i) *Cenchrus ciliaris* grass (IGFRI-3108) and (ii) *C. ciliaris* grass + *Stylosanthes hamata* (var. varano) during the months of August-September 1985. The dry matter intake of groups 1 & 2 were 1.8 kg and 1.6 kg/100 kg b. wt. The crude protein was 9.88 & 13.67%. The herbage utilization by groups 1 and 2 were 60.3 and 61.1% respectively. The daily weight gains observed on grazing *cenchrus* pasture was 203 g/head/day in contrast to 385 g/head/day on mixed pasture.

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2. Evaluation of *Sehima nervosum* dominated natural grassland for growing cross-bred calves.

Eight cross-bred calves (64-133 kg live weight) were allowed for grazing *Sehima nervosum* dominated natural grassland. The average dry matter consumption by the animals was found to be 2.24 kg/100 live weight. The utilization of herbage from this grassland was found to be 60%. The average live weight gain was found to be 181 g/head/day in cross-bred calves grazing natural grassland during the month of October and November 1985.

3. Evaluation of two varieties of hybrid napier grass (Var. IGFRI-3 and NB-21) at mature stage for growing cross-bred calves.

A feeding and digestibility trial was conducted on eight cross-bred calves to evaluate the two varieties of hybrid napier during the month of October-November (100 days growth) 1984. The proximate composition and digestibility coefficients of different nutrients and nutritive value have been presented in table-32.

**Table-32 : Proximate composition, digestibility coefficients and nutritive value of hybrid napier.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Hybrid napier NB-21</th>
<th>Hybrid napier IGFRI-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Proximate composition :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>39.5</td>
<td>34.5</td>
</tr>
<tr>
<td>Crude protein</td>
<td>2.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Ether extract</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>29.5</td>
<td>20.8</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>59.7</td>
<td>62.1</td>
</tr>
<tr>
<td>Total ash</td>
<td>7.2</td>
<td>11.2</td>
</tr>
</tbody>
</table>

(180)
B. Nutritive value:

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestible crude protein</td>
<td>0.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Total digestible nutrients</td>
<td>35.4</td>
<td>48.8</td>
</tr>
<tr>
<td>Dry matter intake per 100% live weight</td>
<td>1.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

The results indicate that feeding hybrid napier grass (var. NB-21 and IGFRI-3) to the growing cross-bred calves, needs supplementation with high protein herbage or with concentrate to get normal growth in calves. However, the feeding value of variety IGFRI-3 was found to be superior to hybrid napier NB-21.

4. Evaluation of dry mature mixed grass with and without concentrate for growing crossbred calves under zero grazing system.

In Bundelkhand region, during summer months, the animals do not get any feed except dry grass and they loose their condition. Concentrate supplementation becomes necessary to avoid such situation and the present experiment was planned to determine the quantum of concentrate supplementation required in such situations. It was observed that the average live weight gain was found to be 275 g/head/day in concentrate supplement group (i) whereas, the animals of control group (ii) lost their live weight @ 236/g/head/day. The dry matter consumption by the calves was found to be higher (2.9 kg/100 kg live weight) in group I as compared to group II i.e. 2.4 kg/100 kg live weight.

The proximate composition, digestibility coefficient of nutrients and nutritive value of dry mature grass and concentrate mixture have been detailed in table-33.

Supplementation of concentrate @ 1 kg/100 kg B.Wt. would not only avoid the loss of weight but also supports a growth rate of 275 g per day in cross-bred calves.
Table-33: Proximate composition, digestibility coefficients of nutrients and nutritive value (dry matter basis)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Dry mature grass</th>
<th>Concentrate mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Proximate composition:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>93.50</td>
<td>91.00</td>
</tr>
<tr>
<td>Crude protein</td>
<td>3.08</td>
<td>19.36</td>
</tr>
<tr>
<td>Ether extract</td>
<td>1.06</td>
<td>4.10</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>36.80</td>
<td>8.50</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>49.30</td>
<td>55.80</td>
</tr>
<tr>
<td>Total ash</td>
<td>9.80</td>
<td>12.20</td>
</tr>
<tr>
<td><strong>B. Digestibility coefficients</strong></td>
<td>Grass alone</td>
<td>Grass + concentrate</td>
</tr>
<tr>
<td>Dry matter</td>
<td>43.86</td>
<td>45.60</td>
</tr>
<tr>
<td>Crude protein</td>
<td>0.00</td>
<td>44.60</td>
</tr>
<tr>
<td>Ether extract</td>
<td>42.10</td>
<td>72.12</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>73.44</td>
<td>56.96</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>33.60</td>
<td>45.88</td>
</tr>
<tr>
<td><strong>C. Drymatter consumption</strong></td>
<td>per 100 kg live weight (kg)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.40</td>
<td>2.90</td>
</tr>
<tr>
<td><strong>D. Average live weight gain</strong></td>
<td>(g/head/day)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-236 g</td>
<td>+275</td>
</tr>
</tbody>
</table>

(Note: The number in parentheses is 182.)
3.2 Evaluation of forages for milk production in cattle.

(V. S. Upadhyay)

1. Evaluation of coastal Bermuda grass (*Cynodon dactylon*) with/without *Leucaena* supplementation for milk production in cattle.

An experiment was conducted to evaluate coastal Bermuda grass with/without *L. leucocephala* supplementation for milk production under cut and feed system. One group of milch cattle was maintained on *ad lib* feeding of Bermuda grass (60–60 days primary growth after onset of monsoon) + 1 kg concentrate mixture/head/day. Second group was maintained on above feeding schedule plus additional supplementation of *L. leucocephala* foliage (leaves with soft twigs) @ 3 percent of live weight (av. 11 kg/h/d). Ten days preliminary feeding was followed by seven days test period during the month of September.

Chemical composition of feed (Percent on D. M. basis) is given below:

<table>
<thead>
<tr>
<th>Feed</th>
<th>D. M.</th>
<th>C. P.</th>
<th>E. E.</th>
<th>C. F.</th>
<th>NDF</th>
<th>Total Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda grass</td>
<td>35.00</td>
<td>5.14</td>
<td>1.11</td>
<td>34.07</td>
<td>52.05</td>
<td>7.63</td>
</tr>
<tr>
<td><em>L. leucocephala</em></td>
<td>25.08</td>
<td>20.55</td>
<td>7.79</td>
<td>20.87</td>
<td>43.37</td>
<td>8.42</td>
</tr>
<tr>
<td>Concentrate</td>
<td>89.00</td>
<td>22.69</td>
<td>0.77</td>
<td>7.99</td>
<td>54.42</td>
<td>14.13</td>
</tr>
</tbody>
</table>

Results indicated that anima's consumed on an average 2.22±0.09 and 2.23±0.12 kg DM/100 L.W in group I & II respectively. The *Leucaena* constituted about 35% of total DM I. The DMD was 47.15±2.85 and 48.30±0.42 percent on above two treatments respectively. Average milk production was 4.30±0.15 and 5.40±0.54 kg/ha/day on above two treatments respectively. Thus *leucaena* supplementation produced about 12.5% more milk. The average fat, total solids and solid-not-fat contents were 4.2, 4.4, 12.98, 12.05 8.7 and 8.8 percent on above two feeding regimes respectively.

3.3 Evaluation of top feeds for goats

(V. S. Upadhyay)

1. Response of adult Barbari goats to supplemental feeding of Subabool *L. leucocephala*,

(183)
An experiment was conducted to study the response of adult male Barbari goats to two different levels of *Leucaena* supplementation and on intake and digestibility of low quality mature dry grass. Twelve adult Barbari male goats having initial average body weight of 21.78 (16.3—25.0) kg were maintained on (a) *ad lib* feeding of mature dry grass (*Sehima-nervosum* and *Heteropogon contortus* dominant), (b) fifty percent dry matter intake (DM I) through green *L. leucocephala* foliage (twigs with soft twigs after chaffing) and remaining 50% through dry grass, and (c) seventy five percent DM I through *Leucaena* and remaining 25% through dry grass for 3 weeks including digestibility trial.

The chemical composition of forage is given below:

<table>
<thead>
<tr>
<th>Forages</th>
<th>D. M.</th>
<th>C. P.</th>
<th>E. E.</th>
<th>C. F.</th>
<th>N. F. E.</th>
<th>Total Ash</th>
<th>Mimosine (2.82—3.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry grass</td>
<td>97.33</td>
<td>3.69</td>
<td>1.51</td>
<td>34.73</td>
<td>48.69</td>
<td>11.38</td>
<td>—</td>
</tr>
<tr>
<td><em>L. leucocephala</em></td>
<td>38.28</td>
<td>18.29</td>
<td>4.75</td>
<td>16.92</td>
<td>48.46</td>
<td>11.58</td>
<td>2.93</td>
</tr>
</tbody>
</table>

DMI and CP intake on an average were $33.22 \pm 1.35, 6.03 \pm 0.53, 57.34 \pm 3.19, 32.01 \pm 2.19$ and $60.34 \pm 3.88, 43.23 \pm 5.69$ g/d/w$^{0.75}$ kg day on treatment (a), (b) and (c) respectively. Dry matter digestibility was $36.02 \pm 1.89, 49.91 \pm 4.13$ and $46.63 \pm 0.89$ percent on treatment (a), (b) and (c) respectively. Total water intake through feed voluntary water was $1489 \pm 46, 2200 \pm 155$ and $2477 \pm 135$ ml/d/head on above three treatments respectively. Urine output was $13.08 \pm 2.05, 30.64 \pm 1.05$ and $43.35 \pm 5.04$ mp/d/w$^{0.75}$ kg on treatment (a), (b) and (c) respectively. Animals of group (a) lost on an average $117 \pm 7.50$ g live weight/ha/day while animals of group (b) and (c) gained $12.5 \pm 4.57$ and $44.75 \pm 8.04$ g/d/y respectively which clearly shows the beneficial effect of *Leucaena* feeding for adult goats.

### 6.1. Economic exploitation of weeds

(B. K. Bhadoria and R. K. Gupta)

1. Investigation on *Sopubia delphinifolia*.

*Sopubia delphinifolia* (N. O. Scrophulariaceae) is a commonly occurring weed in this region. Detailed chemical investigations of this weed were undertaken to isolate and characterise for assessment of its usage in livestock/agricultural productivity.

(184)
The leaves of *Sopubia delphinifolia* were collected from natural grasslands of C. R. Farm and adjoining areas. The leaves were analysed for crude protein (12.7%), ether extract (0.62%), neutral detergent fibre (66.79%) and acid detergent fibre (46.4%).

The shade dried powder leaves of *Sopubia delphinifolia* were further extracted with alcohol by cold percolation for examination of its chemical constituents. The concentrated extract was segregated into petroleum ether, benzene, ethyl acetate and methanol soluble fractions. The ethyl acetate soluble fraction on its concentration and cooling, yielded a yellowish green deposition. The TLC examination of the product revealed two components, which were separated by PLC using ethyl acetate : methanol : water (12 : 1 : 1) as irrigating solvent system. The following compounds were isolated.

Compound I:—Yellow, micro-crystalline substance M. P. 251–53°. It gave cherry red colour with Mg/HCl. It formed as acetate (pyridine + acetic anhydride) MP. 238°–40° IR KBr max 1640, 1380 cm⁻¹. It was hydrolysed with 7% HCl which yielded a dark yellow crystalline aglycone mp. 300° and sugar unit. The sugar moiety was identified as galactose on paper chromatography.

Compound II:—Obtained as dark yellow micro-crystalline MP. 300°. It also responded Shinoda test.

6.2. Investigations on non-conventional feeds and feed additives

(R. K. Gupta)

1. Investigations on *zornia diphylla*

Leguminosae—a pasture legume, commonly grows in the natural grassland. The leaves contain C. P. 23.66% and D. M. 90.24% whereas the whole plant possess C.P. 19.04% and D. M. 92.63%. The proximate nutritional constituents of leaves were ADF 18.24, NDF 28.61, lignin 4.17, cellulose 13.53, E.E. 2.33 and IVTDMD 86.19. The plant did not contain any toxic constituents such as nitrates, oxalates, saponins and cyanogenic glycosides. However, it contained flavonoid glycosides and a small amount mannitol and tannins. The palatability has been good. The plant appears to be quite promising in view of its nutrient contents and acceptability to the livestock.

(185)
2. Investigations on *Borrerla stricta* seed.

*Borrerla stricta* (Rubiaceae) is a common weed of natural grasslands. It occurs widely during monsoon. Earlier studies have shown that the foliage possesses good nutritional value and palatability. Investigations have been carried out on the chemical constituents of the seeds of this unconventional plant for its utilization as livestock feed. The air-dried powdered seeds were fractionated into petroleum ether, benzene, ethyl acetate and alcohol (95%) soluble fractions. These fractions were worked out separately for their chemical constituents.

Petroleum ether fraction yielded a pale yellow fatty oil (3.9%), which was found to be rich in linoleic acid (61.8%). The other acids were oleic 19.2%, palmitic 15.3% and stearic 3.5%. Sitosterol and ursolic acid were identified in benzene and ethyl acetate fractions respectively. Ethanolic fraction contained the flavonoids rutin and quercetin.

Defatted seed meal (C. P. 20.7%) has been analysed for its amino acid composition. It showed the presence of essential as well as non-essential amino acids. The concentration of glycine (10.5%), aspartic acid (9.4%) and leucine (6.4%) was fairly high, while others were relatively low. Methionine (1.3%), tyrosine (1.1%) and histidine (2.2%) were present in very low concentrations. However, other essential amino acids were present in moderate quantities. The seeds do not contain any toxic constituents and could be incorporated in livestock feed as concentrate.
1.1. Mechanical contrivances in hay quality amelioration.

1. Field methods of hay making:

Experiments were undertaken to study the effect of windrow depth, turning frequency, mechanical structures on drying rate and chemical changes of mixed range grasses during hay making process at the farm.

(a) Effect of windrow depth on moisture loss under different drying conditions

The initial moisture content of the grasses varied slightly from period to period. The maximum difference of 6.55 per cent (d. b.) was not considered sufficient to influence the drying rate at any stage of drying (table-34).

(b) Effect on moisture loss:

Windrow depth:

Data on 73 hours of drying duration (table-35) showed a significant decrease in the total moisture loss with the increase in windrow depth. The highest moisture loss of 114.46 per cent was observed in 5 cm windrow against the value of 87.33 per cent obtained in 20 cm windrow. The 10 and 15 cm windrows occupied the intermediate positions showing a difference of 31.07 percent.

Drying weather:

The meteorological data on daily basis for all the experimental periods was collected.
Significant influence of the drying weather on moisture loss was observed, showing the highest value in period III and the lowest in period I. The moisture loss period III exceeded to that of period I by 32.31. The variation in the moisture loss was larger during non-rainy periods and lesser in the rainy periods (table-36.)

(c) Effect of turning frequency on moisture loss from windrows depths

5 cm windrow:

The mean moisture content of the product at the time of 1st, 2nd and 3rd turning treatments was 194.27, 93.61 and 40.44 per cent, respectively (table-37). In the turned windrow, the moisture loss was higher by 29.97 and 11.81 per cent, over the control, respectively, at 1st and 25th observation hour. After 31 hours of drying, the total moisture loss was 129.47, 141.87 and 140.07 per cent from the windrow of zero (Control), one and two turnings respectively, indicating the lead of turned windrow over the control by a margin of 8.81 per cent. However, the 2nd turning did not exhibit any gain in terms of moisture loss. The 3rd turning treatment was applied after 49 hours of drying and the total moisture loss recorded at 55th hour was 158.65, 164.09, 161.77 and 161.08 per cent from the control, one, two and three turnings respectively. This data revealed that the subsequent turnings did not have any beneficial effect on the moisture loss. Further, at the end of the drying period of 79 hours, the moisture loss from the turned windrow was higher by 3.32 per cent indicating thereby greater advantage of turning at the higher moisture content of the product.

15 cm windrow:

The data in table-37 showed that during the first observation hour, the total moisture loss from the turned windrow advanced by 95.33 per cent over the control which dropped down to 21.70 per cent after 31 hours of drying. As in the previous case, the subsequent turning did not exhibit any superiority over one turning.

Hay Drying structures:

Five types of structures, viz., A-Fram, Tripod, Zig-zag fence, Single pole and Multi-tier hay shed were evaluated for drying rate under four weather conditions.

The significant differences in drying rate was observed between A-frame and Hay Shed (table-38). The Tripod, Zig-zag fence and Single pole did not exhibit any significant
difference. A-Fram resulted in the highest drying rate of $14.98 \text{g } H_2O/h-kg \text{ dry matter}$ followed by Zig-zag fence (14.61) and single pole (14.54). The drying rate in A-Fram exceeded to that of Zig-zag fence and Hay shed, respectively, by 2.32 and 49.05 per cent.

(d) Effect of drying weather:

Difference in the drying rate among the periods was also significant. The highest drying rate of 16.73 $g \text{H}_2\text{O}/h-kg \text{ matter}$ was noted in period III followed by 15.97 in period I. The lowest drying rate was observed during period IV.

Chemical changes during hay drying:

The effect of different hay drying methods on the conservation of the nutrients was studied for the loss of crude protein (CP) and in vitro true dry matter digestibility (IVTDMD) by laboratory analysis. The results obtained on these aspects have been presented as below.

(e) Effect of depth of windrow and turning frequency on crude protein:

(i) Depth of Windrow: During non-rainy days, windrow depth exhibited a great influence on the loss of CP. (table-39) In all cases, the loss increased with the increase in depth. However, marked differences were noted when the depth was increased from 5/10 cm to 15 cm, for both the turned and unturned windrows.

(ii) Turning Frequency: The loss of CP as a result of turning the drying crop, showed an interesting relationship with the number of turnings applied. The data (table-40) exhibited decrease in the loss of CP from 10.58 to 10.04 per cent (though not statistically significant) from zero turning (control) to two turnings, but when the crop was turned three times, the loss of CP increased from 10.04 to 10.59 per cent.

Structure for Hay Making:

The results presented in (table-41), showed that the loss of CP (14.11 per cent) was the least in hay prepared in shed and the highest (18.75 per cent) in hay made as single pole. However, there was no significant difference in the loss of CP in the hay prepared using Hay Shed, A-frame, Tripod fence and the single pole.

Weather conditions: In all cases, the loss of CP was markedly influenced by the weather conditions. It was the minimum in non-rainy periods and the maximum in rainy periods (table-41). The field drying duration was observed to be weather dependent showing a linear relationship with the loss of CP.
(f) Effect on \textit{in vivo} true dry matter digestibility windrow depth:

From the data (table-42), it was observed that IVTDMD values decreased slightly (40.72, 40.67, 40.44 and 40.37) with the increase in windrow depth (5.10, 15.20 cm, respectively). The non significant difference in the IVTDMD values of 37.51 and 37.59 per cent in 4 and 15 cm windrows, respectively, further indicated a little influence of the windrow depth on IVTDMD values of the product.

Turning frequency:

The IVTDMD values increased slightly with the number of turnings applied (table 43). The minimum value of 37.44 per cent at zero turning (Control), and the maximum value of 37.67 per cent at three turning were recorded.

Structures of hay making:

The effect of different hay drying structures on the IVTDMD values of the product are presented in (table-44). Significantly higher values of IVTDMD (32.96 and 39.57 per cent) were obtained in hay made on Hay Shed and A-frame, respectively, compared to 38.85 per cent obtained from Tripod. However, no significant difference was observed among Tripod, Zig-zag fence and Single Pole. The lowest value of 38.52 per cent was observed in Zig-zag fence.

Table-34 : Variation in the initial moisture content on grass used for studying the effect of windrow depth on moisture loss

<table>
<thead>
<tr>
<th>Windrow depth</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>169.18</td>
<td>166.99</td>
<td>170.31</td>
<td>171.43</td>
<td>178.75</td>
<td>184.03</td>
</tr>
<tr>
<td>10</td>
<td>168.75</td>
<td>167.49</td>
<td>179.14</td>
<td>172.82</td>
<td>180.75</td>
<td>185.02</td>
</tr>
<tr>
<td>15</td>
<td>167.29</td>
<td>168.66</td>
<td>179.21</td>
<td>178.21</td>
<td>177.88</td>
<td>184.16</td>
</tr>
<tr>
<td>20</td>
<td>168.06</td>
<td>170.13</td>
<td>178.81</td>
<td>186.79</td>
<td>191.25</td>
<td>185.01</td>
</tr>
</tbody>
</table>

( 190 )
Table-35: Final moisture content and overall drying rate of grass hay dried in windrow of different depths.

<table>
<thead>
<tr>
<th>Treatment Windrow depth (cm)</th>
<th>Initial Moisture content</th>
<th>Final Moisture content</th>
<th>Moisture loss, %, d. b.</th>
<th>Drying duration h</th>
<th>Drying rates percent moisture/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Period I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>169.18</td>
<td>29.07</td>
<td>141.11</td>
<td>73</td>
<td>1.92</td>
</tr>
<tr>
<td>10</td>
<td>168.75</td>
<td>30.15</td>
<td>138.60</td>
<td>73</td>
<td>1.90</td>
</tr>
<tr>
<td>15</td>
<td>167.29</td>
<td>26.93</td>
<td>140.36</td>
<td>97</td>
<td>1.45</td>
</tr>
<tr>
<td>20</td>
<td>168.06</td>
<td>27.00</td>
<td>141.06</td>
<td>103</td>
<td>1.37</td>
</tr>
<tr>
<td>Period II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>166.99</td>
<td>26.06</td>
<td>140.93</td>
<td>73</td>
<td>1.93</td>
</tr>
<tr>
<td>10</td>
<td>167.40</td>
<td>26.05</td>
<td>141.44</td>
<td>73</td>
<td>1.94</td>
</tr>
<tr>
<td>15</td>
<td>168.66</td>
<td>24.65</td>
<td>144.01</td>
<td>87</td>
<td>1.65</td>
</tr>
<tr>
<td>20</td>
<td>170.13</td>
<td>24.95</td>
<td>145.18</td>
<td>93</td>
<td>1.56</td>
</tr>
<tr>
<td>Period III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>179.31</td>
<td>28.37</td>
<td>150.94</td>
<td>73</td>
<td>2.07</td>
</tr>
<tr>
<td>10</td>
<td>179.14</td>
<td>30.43</td>
<td>148.71</td>
<td>73</td>
<td>2.04</td>
</tr>
<tr>
<td>15</td>
<td>179.21</td>
<td>30.92</td>
<td>148.29</td>
<td>103</td>
<td>1.44</td>
</tr>
<tr>
<td>20</td>
<td>178.81</td>
<td>30.32</td>
<td>148.43</td>
<td>121</td>
<td>1.23</td>
</tr>
</tbody>
</table>

(191)
Table 36: Effect of windrow depth on total moisture loss during field method of hay making.

<table>
<thead>
<tr>
<th>Windrow depth (cm)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>97.00</td>
<td>107.05</td>
<td>139.33</td>
<td>114.46</td>
</tr>
<tr>
<td>10</td>
<td>91.67</td>
<td>103.95</td>
<td>117.23</td>
<td>104.28</td>
</tr>
<tr>
<td>15</td>
<td>84.02</td>
<td>84.60</td>
<td>107.74</td>
<td>92.12</td>
</tr>
<tr>
<td>20</td>
<td>79.66</td>
<td>80.47</td>
<td>101.86</td>
<td>87.33</td>
</tr>
<tr>
<td>Mean</td>
<td>88.08</td>
<td>94.02</td>
<td>116.54</td>
<td>99.55</td>
</tr>
</tbody>
</table>

SE (m)         C. D. at 5%
Depth         0.5456       1.0802
Period        0.4725       0.9365

(192)
Table-37: Effect of turning frequency on moisture loss from grass at different stages of drying

<table>
<thead>
<tr>
<th>Hours after harvest</th>
<th>Turning x-0</th>
<th>Turning x-1</th>
<th>Turning x-2</th>
<th>Turning x-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>195.52</td>
<td>195.26</td>
<td>193.24°</td>
<td>194.17°</td>
</tr>
<tr>
<td>1</td>
<td>16.99</td>
<td>21.93</td>
<td>22.31</td>
<td>22.09</td>
</tr>
<tr>
<td>7</td>
<td>61.77</td>
<td>74.11</td>
<td>73.13</td>
<td>72.27</td>
</tr>
<tr>
<td>21</td>
<td>65.88</td>
<td>77.00</td>
<td>75.98</td>
<td>75.21</td>
</tr>
<tr>
<td>25</td>
<td>91.97</td>
<td>102.83</td>
<td>101.43</td>
<td>97.72</td>
</tr>
<tr>
<td>31</td>
<td>129.47</td>
<td>141.87</td>
<td>140.09°</td>
<td>140.00°</td>
</tr>
<tr>
<td>45</td>
<td>130.59</td>
<td>142.79</td>
<td>140.33</td>
<td>139.98</td>
</tr>
<tr>
<td>49</td>
<td>145.34</td>
<td>155.75</td>
<td>154.33</td>
<td>163.32</td>
</tr>
<tr>
<td>55</td>
<td>158.65</td>
<td>164.09</td>
<td>161.77</td>
<td>161.08°</td>
</tr>
<tr>
<td>69</td>
<td>158.70</td>
<td>164.14</td>
<td>161.87</td>
<td>161.16</td>
</tr>
<tr>
<td>73</td>
<td>163.94</td>
<td>169.39</td>
<td>167.01</td>
<td>167.67</td>
</tr>
</tbody>
</table>

(193)
Table-37: (contd).

<table>
<thead>
<tr>
<th>Hours</th>
<th>Turning x-0</th>
<th>Turning x-1</th>
<th>Turning x-2</th>
<th>Turning x-3</th>
<th>Turning x-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>193.15</td>
<td>193.68°</td>
<td>193.79°</td>
<td>193.53°</td>
<td>193.55°</td>
</tr>
<tr>
<td>1</td>
<td>9.42</td>
<td>18.40</td>
<td>18.26</td>
<td>17.04</td>
<td>17.90</td>
</tr>
<tr>
<td>7</td>
<td>45.43</td>
<td>64.98</td>
<td>64.62</td>
<td>64.82</td>
<td>66.12</td>
</tr>
<tr>
<td>21</td>
<td>50.06</td>
<td>68.11</td>
<td>68.02</td>
<td>67.95</td>
<td>69.11</td>
</tr>
<tr>
<td>25</td>
<td>74.21</td>
<td>91.15</td>
<td>92.16</td>
<td>91.67</td>
<td>92.96</td>
</tr>
<tr>
<td>31</td>
<td>93.41</td>
<td>113.31</td>
<td>113.04°</td>
<td>112.93°</td>
<td>113.84°</td>
</tr>
<tr>
<td>45</td>
<td>95.76</td>
<td>115.41</td>
<td>115.19</td>
<td>115.03</td>
<td>115.98</td>
</tr>
<tr>
<td>49</td>
<td>108.35</td>
<td>128.48</td>
<td>127.94</td>
<td>127.63</td>
<td>128.23</td>
</tr>
<tr>
<td>55</td>
<td>121.38</td>
<td>138.87</td>
<td>139.54</td>
<td>138.71°</td>
<td>140.73°</td>
</tr>
<tr>
<td>69</td>
<td>123.81</td>
<td>141.07</td>
<td>141.64</td>
<td>140.90</td>
<td>142.97</td>
</tr>
<tr>
<td>73</td>
<td>130.83</td>
<td>148.06</td>
<td>148.57</td>
<td>148.10</td>
<td>149.91</td>
</tr>
<tr>
<td>79</td>
<td>137.05</td>
<td>154.22</td>
<td>154.83</td>
<td>154.26</td>
<td>156.01°</td>
</tr>
<tr>
<td>93</td>
<td>138.96</td>
<td>156.08</td>
<td>156.21</td>
<td>155.99</td>
<td>157.78</td>
</tr>
<tr>
<td>97</td>
<td>143.00</td>
<td>160.18</td>
<td>160.41</td>
<td>159.95</td>
<td>161.83</td>
</tr>
<tr>
<td>103</td>
<td>148.58</td>
<td>165.53</td>
<td>164.83</td>
<td>165.46</td>
<td>166.89</td>
</tr>
</tbody>
</table>

°, °°, °°° and °°°° indicate the time of one, two, three and four turning treatments respectively.

(194 )
Table-38 : Drying rate of grass hay on hay drying structures.

<table>
<thead>
<tr>
<th>Period</th>
<th>A-Frame</th>
<th>Tripod</th>
<th>Zig-zag fence</th>
<th>Single pole</th>
<th>3-Tier hay drying shed</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12.94</td>
<td>12.52</td>
<td>12.67</td>
<td>12.60</td>
<td>8.78</td>
<td>11.90</td>
</tr>
<tr>
<td>II</td>
<td>17.69</td>
<td>16.85</td>
<td>17.06</td>
<td>16.88</td>
<td>11.38</td>
<td>15.97</td>
</tr>
<tr>
<td>III</td>
<td>18.50</td>
<td>17.79</td>
<td>18.22</td>
<td>18.15</td>
<td>11.00</td>
<td>16.73</td>
</tr>
<tr>
<td>IV</td>
<td>10.78</td>
<td>10.52</td>
<td>10.59</td>
<td>10.55</td>
<td>9.02</td>
<td>10.29</td>
</tr>
<tr>
<td>Mean</td>
<td>14.98</td>
<td>14.42</td>
<td>14.64</td>
<td>14.54</td>
<td>10.05</td>
<td>13.73</td>
</tr>
</tbody>
</table>

S. E. (D) C. D. at 5%
Structure 0.1369 0.2710
Period 0.1225 0.2425
Structure x period 0.2739 0.5422

Table-39 : Loss of crude protein in field methods of grass hay making in windrows of different depth.

<table>
<thead>
<tr>
<th>Period</th>
<th>Windrow depth, cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>I</td>
<td>10.81</td>
</tr>
<tr>
<td>II</td>
<td>11.38</td>
</tr>
<tr>
<td>III</td>
<td>11.20</td>
</tr>
<tr>
<td>Mean</td>
<td>11.13</td>
</tr>
</tbody>
</table>
Table-40: Loss of crude protein in grass hay as influenced by different turning frequencies.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Loss of crude protein, (% D. M. basis)</th>
<th>Mean windrow depth, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turning x-0</td>
<td>9.36 11.79</td>
<td>10.58</td>
</tr>
<tr>
<td>Turning x-1</td>
<td>9.42 11.58</td>
<td>10.50</td>
</tr>
<tr>
<td>Turning x-2</td>
<td>9.34 10.75</td>
<td>10.04</td>
</tr>
<tr>
<td>Turning x-3</td>
<td>9.51 11.69</td>
<td>10.59</td>
</tr>
<tr>
<td>Mean</td>
<td>9.41 11.45</td>
<td>10.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S. E. (D)</th>
<th>C. D. at 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>0.3725</td>
</tr>
<tr>
<td>Period</td>
<td>0.3226</td>
</tr>
<tr>
<td>Depth x Period</td>
<td>0.4163</td>
</tr>
</tbody>
</table>

NS :—Not significant.

( 196 )
Table 41: Loss of crude protein in grass hay dried on different structures.

Loss of crude protein, (% D. M. basis)

<table>
<thead>
<tr>
<th>Period</th>
<th>Structures</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-fram</td>
<td>Tripod</td>
</tr>
<tr>
<td>I</td>
<td>10.51</td>
<td>11.29</td>
</tr>
<tr>
<td>II</td>
<td>19.40</td>
<td>20.23</td>
</tr>
<tr>
<td>III</td>
<td>22.27</td>
<td>30.61</td>
</tr>
<tr>
<td>IV</td>
<td>9.21</td>
<td>9.95</td>
</tr>
<tr>
<td>Mean</td>
<td>15.35</td>
<td>18.02</td>
</tr>
</tbody>
</table>

S.E.(D) C. D. at 5%

- Structure: 1.4038 2.7794
- Period: 1.2559 2.4866
- Structure x Period: 2.8076 5.5588

(197)
Table-42 : Effect of field methods and grass hay making in windrows of different depths on *in vitro* true dry matter digestibility (IVTDMD).

<table>
<thead>
<tr>
<th>Periods</th>
<th>Windrow depth, cm</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td></td>
<td>40.84</td>
<td>40.32</td>
<td>43.21</td>
<td>40.48</td>
</tr>
<tr>
<td>II</td>
<td></td>
<td>40.66</td>
<td>40.83</td>
<td>40.52</td>
<td>40.29</td>
</tr>
<tr>
<td>III</td>
<td></td>
<td>40.65</td>
<td>40.86</td>
<td>40.87</td>
<td>40.33</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>40.72</td>
<td>40.67</td>
<td>40.44</td>
<td>40.37</td>
</tr>
</tbody>
</table>

S. E.(D) | C. D. at 5%
Depth     | 0.2299 | 0.4534
Period    | 0.1983 | 0.3926
Depth x Period | 0.3966 | 0.7852

Table-43 : Effect of different turning frequencies on *in vitro* true dry matter digestibility of grass hay.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Windrow depth, cm</th>
<th>5</th>
<th>15</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning x-0</td>
<td></td>
<td>37.50</td>
<td>37.38</td>
<td>37.44</td>
</tr>
<tr>
<td>Turning x-1</td>
<td></td>
<td>37.39</td>
<td>37.63</td>
<td>37.51</td>
</tr>
<tr>
<td>Turning x-2</td>
<td></td>
<td>37.43</td>
<td>37.74</td>
<td>37.59</td>
</tr>
<tr>
<td>Turning x-3</td>
<td></td>
<td>37.73</td>
<td>37.61</td>
<td>37.67</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>37.51</td>
<td>37.59</td>
<td>37.55</td>
</tr>
<tr>
<td>Period</td>
<td>A-Frame</td>
<td>Tripod</td>
<td>Zig-zag fence</td>
<td>Single pole</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>---------------</td>
<td>-------------</td>
</tr>
<tr>
<td>I</td>
<td>41.36</td>
<td>41.07</td>
<td>40.75</td>
<td>40.39</td>
</tr>
<tr>
<td>II</td>
<td>38.38</td>
<td>38.25</td>
<td>37.93</td>
<td>37.78</td>
</tr>
<tr>
<td>III</td>
<td>37.55</td>
<td>35.59</td>
<td>34.82</td>
<td>35.41</td>
</tr>
<tr>
<td>IV</td>
<td>40.99</td>
<td>40.49</td>
<td>40.58</td>
<td>40.67</td>
</tr>
<tr>
<td>Mean</td>
<td>39.75</td>
<td>38.85</td>
<td>38.52</td>
<td>38.56</td>
</tr>
</tbody>
</table>

S. E. (D)+C. D. at 5%

<table>
<thead>
<tr>
<th></th>
<th>Structure</th>
<th>Period</th>
<th>Structure x Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.3606</td>
<td>0.3225</td>
<td>0.7211</td>
</tr>
<tr>
<td>Mean</td>
<td>0.7140</td>
<td>0.6485</td>
<td>10.4277</td>
</tr>
</tbody>
</table>

( 199 )
2.1. Effect of package of improved implements on the cost of production of wheat, Jowar grain and fodder M. P. Chari

(Jai Singh)

Wheat: Three packages of improved implements M. B. plough, *Triphali*, IGFRI single row drill and IGFRI Channel Former in P<sub>2</sub>, M. B. Plough, *Triphali*, B. D. disc harrow, IGFRI two-row drill and IGFRI Channel Former in P<sub>3</sub>, and M. B. plough, *Triphali*, B. D. disc harrow, Aligarh three-row drill and IGFRI Channel Former in P<sub>4</sub> were tested against the common package of implements (P<sub>1</sub>), viz., M. B. Plough, *desi* plough, local *bukhar*, *nari* and *pachiya* for cost of wheat production under irrigated conditions in the adopted village. The cost on tillage and seeding operations amounting to Rs. 1477.27/ha was highest in P<sub>1</sub> followed by Rs. 1044.70 in P<sub>3</sub>. Thus, the cost in P<sub>1</sub> was 29.28% higher than P<sub>3</sub>. This difference between P<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub> was not significant. The cost benefit ratio of 2.223 was also highest in P<sub>3</sub> followed by 2.189 in P<sub>4</sub> and 2.156 in P<sub>2</sub>. The value of cost-benefit ratio of 1.235 was lowest in P<sub>1</sub>.

Jowar (Grain crop): Two packages of implements, viz, M. B. Plough, *Desi* Plough and *Khurpi* in P<sub>1</sub> (control) and M. B. Plough, *Triphali*, IGFRI single-row drill and IGFRI weeder mulcher in P<sub>2</sub> (improved) were compared for Jowar grain crop cultivation on farmer’s fields in the adopted village. The cost on tillage and seeding operations were Rs. 296.26 and Rs. 543.93 in P<sub>1</sub> and P<sub>2</sub>, respectively. However, a higher cost benefit ratio of 1.22 was observed in P<sub>2</sub> than a value of 0.59 in P<sub>1</sub>. The cost benefit ratio in P<sub>1</sub> increased due to (i) increase in yield by 28.78% and (ii) reduction in the cost of weeding by more than two and a half times.

Fodder M. P. Chari: Two packages of improved implements M. B. Plough+*Triphali* IGFRI single row drill in P<sub>2</sub> and M. B. Plough+*Triphali*+Aligarh three-row drill in P<sub>2</sub> were compared with the traditional method of cultivation P<sub>1</sub> for M. P. Chari production for fodder purpose at the state livestock-cum-Agricultural farm Bharari. The cost of tillage and seeding operations was highest in P<sub>2</sub> (Rs. 249.44/ha) followed by Rs. 218.04/ha in P<sub>1</sub> and lowest of Rs. 193.59 in P<sub>3</sub>. However, the cost benefit ratio of 3.54 was highest in P<sub>2</sub> followed by 3.237 in P<sub>3</sub> and lowest value of 2.531 in P<sub>1</sub>. This was due to the increased yield of green fodder by 37.26% in P<sub>2</sub> over P<sub>1</sub>.
2.2. Comparative performance of local and CIAE sickle

The local and CIAE Sickles were tested in harvesting wheat (2.654 ha) fodder M. P. Chari (3.065 ha) and grasses (2.7 ha). The local sickle gave better performance over the CIAE sickle in harvesting wheat crop. The mean values of product of area covered and weight of crop harvested per worker per day were 3435.7 and 3232.8 for local and CIAE sickle, respectively. In grass harvesting, both the sickles gave almost equal performance. The values of the area X weight of crop per worker/day were 1777.1 and 1987.3 for local and CIAE sickles, respectively. The CIAE sickle proved to be significantly more efficient in harvesting M. P. Chari over the local sickle. The values of the area covered weight of crop were 6338.6 and 6745.9 for local and CIAE sickles respectively.

2.3. Comparative performances of local and improved tool in harvesting subabool seed.

The local tool called Ghukiya and IGFRI pod plucker were compared for harvesting subabool seed. The use of IGFRI pod plucker resulted in higher seed yield, caused lesser damage to the plant as well to the seed in comparison to the local tool. Therefore, the IGFRI pod plucker can be considered for extension programme.

AE-3 : EVALUATION OF DIFFERENT METHODS OF IRRIGATION IN RELATION TO FORAGE CROPS.

3.1. Studies on the effect of different mechanical energy input levels on the production of forage crops.

(R. B. Varshney and Jai Singh)

Energy required for cultivation of M. P. Chari and oat crops, was recorded on different unit operations under different tillage and seeding treatments. The treatments consisted of T1—Direct seeding without preparatory tillage, T2—Ploughing once, T3—ploughing twice and T4—ploughing thrice. In all cases sowing was done using IGFRI drill. The results indicated a positive effect of the energy used on yield.
3.2. To study the effect of different vegetative covers and degree of slope on run off and soil loss.

(R. B. Varshney and Jai Singh)

Run off and soil loss on micro-watershed was measured. The soil characteristics of the watershed area were: bulk density-1.5 g/cc, soil depth-20-30 cm, soil texture-sand 73.8%, silt 6.8% and clay 19.4%. The average run off coefficient observed was 0.07, 0.11 and 0.15 and the average soil loss measured was 1.5, 2.5, and 3.6 t/ha for 3.5 and 10 per cent slopes, respectively.
1.1 Farm structure, resource use, productivity and profitability of irrigated farming system in Chirgaon block of Jhansi district with special reference to forage crop under different farm sizes.

(I. P. S. Yadav)

Cost–benefit ratio, production potentiality and profitability of forage and grain crop on farmer fields:

Break-up of input cost for different input factors per hectare on different size of holdings were worked out. The study showed that the average per hectare total cost of cultivation of mixed crops of jowar + Arhar increased with the increasing size of farm ranging from Rs. 660.60 on smallest size group to Rs. 779.56 on largest size group of holdings and Rs. 748.64 for an average farm holding. This increase was due to higher investment on cash inputs. The bullock labour cost per hectare was highest on lowest size of farm due to the higher cost of maintenance for per pair of bullock on smaller farms. The overhead cost per hectare, showed the increasing trend with the increase in the size of farms because of the agricultural machinery and irri gational equipments maintained on the medium and large size group of holdings. The study further revealed that the bullock labour and human were the main items of cost on an average accounting for 34.04 percent and 23.76 percent of the total input cost, next to the rental value of land contributing 33.38 percent, seed cost 3.21 percent and overhead cost for 5.61 percent to the total cost.

On an average, the per quintal cost of production of main and by products of jowar came to Rs. 50.49 and Rs. 5.83, respectively. The cost of production study revealed that
per quintal cost production of main and by products of *arhar* decreases with an increase in the size group of holdings. It varied from Rs. 135.42 on smallest holding to Rs. 103.87 on largest size. Similarly, an average per quintal, cost of production of main and by product of *arhar* came to Rs. 116.52 and Rs. 3.88 respectively.

Net income, family labour income, farm business income per hectare and cost benefit ratio on jowar-*arhar* was worked out. The data revealed that on an average jowar-*arhar* yielded, per hectare a net profit of Rs. 1178.91 showing the increasing trend with an increase in the size group of holding with exception in largest size group being Rs. 802.85, Rs. 1205.70, Rs. 1455.27 and 1186.44 on the farm of 0-7 hectare, 1-3 hectare, 3-6 hectare and 6 and above hectares size group of holdings, respectively. The family labour income and farm business income showed a similar trend as in the net profit on different size of holdings. On an average, per hectare, output net profit, family labour income and farm business income came to Rs. 1927.55, Rs. 1178.91, Rs. 1284.32 and Rs. 1291.40 respectively. The cost benefit ratio on an average farmer of sample in jowar-*arhar* came to 2.57, showing increasing trend with an increase on the size group of holdings, with exception of largest size group.

On an average, jowar yielded 4.38 quintal of grain and 35.16 quintal byproduct (*kadbi* fodder) per hectare which varied from 3.54 quintal on the farms of smallest size group to 5.00 quintal grain on the farms of 3-5 hectare size groups and 23.33 quintal fodder on the farms of smallest size group to 40.30 quintal on the farms of 3-6 hectare size group of holdings, afterwards it declined on the farms of largest size groups. The data also showed that the average yield of *arhar* (grain) and by-product (*bhusa*) came to 2.47 and 8.99 quintal per hectare and value of output was Rs. 741.00 and Rs. 89.90 per hectare respectively.

1.2 Impact of forage production technologies on productivity and income under out-reach programme.

(I. P. S. Yadav)

Under research and development of the Institute, covering three districts i.e. two from Haryana (Gurgaon and Makendragarh) and one from Madhy Pradesh (Durg), the impact of forage production technology was evaluated on the basis of field demonstrations conducted from 1983 to 1985.

It has also been found that the adoption of forage production technology has increased these villages from 30 to 40 per cent. The economic evaluation of out-reach programme
at Gurgaon and Mahendragarh district revealed that on an average net income per hectare from berseem increased to about Rs. 6366.03 on the demonstrated farms. The cost of cultivation per hectare was worked out to be Rs. 2345.97, per quintal cost of production for berseem was Rs. 4.30 and cost-benefit ratio was 3.71.

The study on cost of cultivation for pusa chari-6 and maize for fodder at Gurgaon and Mahendragarh districts revealed that the over all average per hactare cost of cultivation was Rs. 1592.16 and Rs. 1714.20 giving net income per hactare Rs. 1495.68 and 1811.70 respectively. Cost-benefit ratio for chari and maize was 1:1.94 and 1:2.05 respectively. The per quintal cost of production of chari and maize worked out to be Rs. 7.22 and Rs. 6.80 respectively.

The average productivity of different fodder crops viz, chari, maize and berseem were 220.50 q, 151.85 q. and 544.56 q. per hactare giving a gross returns of Rs. 3087.84, Rs. 3525.90 and Rs. 8712.00 per hactare respectively.

1.3 Economics of forage production and forage based animal production system—studies based on data from experiments and demonstration trials laid out at the C. R. farm experimental farms.

(Ram Asrey Singh)

1. Studies on response of maize varieties to nitrogen levels:

The experiment was conducted at C. R. Farm by “Dryland Agriculture Scheme” Soil Science Division to test the performance of four maize varieties (Gang-2, Ganga-5, Vijay and African tall) with 4 levels (0, 25, 50 and 75, N/ha) of nitrogen. The data on the output (yield of maize varieties) ar d input (different levels of nitrogen) were taken as independent variable respectively and the multiple regression analysis were fitted to the data. The analysis of variance showed that the effects of levels of nitrogen, varieties and interaction of nitrogen and variety were highly significant. Thus to examine the trends of yield Y on nitrogen X, the linear quadratic and cubic components are calculated separately for each variety. It is observed that the response to nitrogen application was quadratic for the varieties Ganga-2, Ganga-5 and Vijay and was linear for the African tall for nitrogen application between 0 to 75.0 kg/ha.

(205)
The dose x (nitrogen kg/ha.) and response Y (yield q/ha.) relationship for the varieties is as given below:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Dose—response relationship</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganga–2</td>
<td>$Y = 1.63588 + 3.370136 X - 0.620512 X^2$</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>(0.1508) (0.0871)</td>
<td></td>
</tr>
<tr>
<td>Ganga–5</td>
<td>$Y = 2.1019 + 2.7634 X - 0.4680 X^2$</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>(0.4981) (0.1591)</td>
<td></td>
</tr>
<tr>
<td>Vijay</td>
<td>$Y = 1.5929 + 3.6174 X - 0.7089 X^2$</td>
<td>0.9983</td>
</tr>
<tr>
<td></td>
<td>(0.2533) (0.0809)</td>
<td></td>
</tr>
<tr>
<td>African Tall</td>
<td>$Y = 1.4691 + 0.4064 X$</td>
<td>0.9073</td>
</tr>
<tr>
<td></td>
<td>(0.0914)</td>
<td></td>
</tr>
</tbody>
</table>

Note: (Figures in parenthesis give the S. E. of the regression coefficients)

The $R^2$-values show that the relationship gave a good-fit to the dose explaining 98%, 99%, 99% and 91% of variation for the varieties.

The Agronomic optimum dose of nitrogen for different varieties is as under:

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Agronomic Optimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganga–2</td>
<td>67.90 kg/ha.</td>
</tr>
<tr>
<td>Ganga–5</td>
<td>73.97 kg/ha.</td>
</tr>
<tr>
<td>Vijay</td>
<td>63.79 kg/ha.</td>
</tr>
</tbody>
</table>
For the economic optimum we may take different prices of output (Rs. 125, 150, 175, 200 and 225)/kg and input (Rs. 4.50, 4.75, 5.00, 5.25 and 5.50)/kg.

It is observed that the economic optimum dose for the maize varieties Gang-2, Ganga-S and Vijay varied from 57.94 to 63.37, 62.72 to 67.94 and 55.05 to 59.82 respectively. Accordingly the mean value are 61.43, 65.36 and 58.12 for economic optimum dose of nitrogen for above three varieties of maize. The agronomic optimum for these varieties are 67.90 : 73.97 and 63.79 kg. nitrogen per hectare which is higher than the economic optimum.

2. Effect of nitrogen and phosphate on seed production of *pennisetum polystachyon*.

The experiment was conducted at C. R. Farm by Division of "Seed Technology" during year 1983-84 and 1984-85 to test the effect of nitrogen and phosphate on seed production of *pennisetum polystachyon*. Five levels (0, 30, 60, 90 and 120 kg N/ha.) of nitrogen and three levels of phosphate (0, 30 and 60 kg P/ha.) were applied to select the optimum dose of fertilizer for obtaining the maximum seed and straw yield.

The data on output (seed and straw yield of *pennisetum polystachyon*) and input (different levels of nitrogen and phosphate) were taken as the dependent variable and independent variable, respectively. The multiple regressions analysis were fitted to the data. It is observed that the main effects of levels of nitrogen and phosphate were significant and the nitrogen x phosphorus interaction was not significant. For trends of yield Y on nitrogen X1 and phosphate X2, the linear quadratic cubic etc. components were calculated separately for nitrogen and phosphate.

It is observed that the response to nitrogen application was quadratic and it was linear for phosphate application (0 to 60 kg/ha.)

The dose $X_1 = $ (nitrogen kg/ha) and $X_2 = $ (phosphate kg/ha) and response (Y = yield kg/ha) relationship for the *pennisetum polystachyon* is as given below:

$$Y = -1.622471 + 0.5416X_1 - 0.0129X_1^2 + 0.3806X_2$$

$SE (b) = (0.08518) (0.00154) (0.1475)$  

$R^2 = 0.92$

**Note:** Figures in parenthesis give the SE of the regression coefficients.
The $R^2$—values show that the relationship gave a good fit to the dose response relationship explaining 92% of variation by the nutrients nitrogen and phosphate.

The agronomic optimum dose of nitrogen for *pennisetum polystachyon* is 28.81 kg/ha. The response to application of phosphate to *pennisetum polystachyon* being only linear, no optimum level of phosphorus can be obtained.

For the economic optimum dose of nitrogen we may take different prices of output viz Rs. 2000, 3000, 4000, 5000 & 6000/q of seed and input (Rs 4.50, 4.75, 5.00, 5.25 and 5.50) /kg of nitrogen. The optimum doses for various combinations of price of output (sa’e) and input (purchase) were foundout.

It is observed that on the different price of input and output the economic optimum dose for *pennisetum polystachyon* varied from 28.77/9 to 28.80/2 which is in close proximity to agronomic optimum of 28.81 kg nitrogen per hectare. Thus for seed production nitrogen, application of 28.8 kg/ha could be recommended under the conditions of the experiment. The analysis of variance of straw yield shows that effects of levels of nitrogen phosphate and interaction of nitrogen and phosphate were highly significant. Thus, to examine the trends of yield $Y$ on $X_1$ and $X_2$, the linear, quadratic, cubic and quartic components were calculated. It is observed that the linear, quadratic and cubic components of nitrogen and linear component of phosphorus are significant. The significant components of interaction Nitrogen x Phosphorus are linear x quadratic and quartic x quadratic.

Since the quartic component of main effect of nitrogen and quadratic component of main effect of phosphorus are not significant. The dose $X_1$ (nitrogen kg/ha), $X_2$ (phosphate kg/ha.) and response $Y$ (yield q/ha.) relationship for the *pennisetum polystachyon* is as given below:

$$Y = 143.05 - 16.57 X_1 - 3.38 X_1^2 + 17.09 X_1 X_2 + 54.82 X_1 X_2^2 - 1.10 X_1^4 X_2^3$$  \[ R^2 = 0.92 \]

The nature of equation has not given the optimum dose nitrogen and phosphorus,

$$(X_1=N/30)$$

$$(X_2=P/30)$$
The analysis of variance shows that the main effects of levels of nitrogen and phosphate were significant and the nitrogen and phosphorus interaction was not significant. To examine the trends of yield $Y$ on nitrogen $X_1$ and phosphates $X_2$, the linear, quadratic, cubic and quartic components are calculated separately for nitrogen and phosphorus. It is observed that the response to nitrogen and phosphorus was only linear.

The dose $X_1$ (nitrogen kg/ha) and $X_2$ (phosphate kg/ha) and response ($Y$=yield q/ha) relationship for the *pennisetum polystachyon* is as given below:

$$Y = 165.868 + 0.5217 X_1 + 0.9648 X_2$$

$SE$ (0.08911) (0.154341) $R^2$=0.86

(Figures given in parenthesis are the S. E. of the regression coefficients).

The $R^2$ value shows that the response relationship gave a good fit to the dose explaining 86% variation by the nutrients nitrogen and phosphate.

The above analysis shows that the main effects of levels of nitrogen and phosphate were significant and the nitrogen and phosphorus interaction was not significant. To examine the trends of yield $Y$ on nitrogen $X_1$ and phosphorus $X_2$, the linear, quadratic, cubic and quartic components are calculated separately for nitrogen and phosphorus.

From the analysis we observe that the response to nitrogen and phosphorus was only linear.

The dose $X_1$ (nitrogen kg/ha) and $X_2$ (phosphate kg/ha) and response ($Y$=yield q/ha) relationship for the *pennisetum palystachyon* is as given below:

$$Y = 8.7081 + 0.0078338 X_1 + 9.008928 X_2$$

$SE$ (0.001024) (0.001346) $R^2$=0.8952

(Figures given in parenthesis are the S. E. of the regression coefficients).

The $R^2$ value shows that the response relationship gave a good fit to the dose explaining 89% variation by the nutrients nitrogen and phosphorus.
1.4 Studies on relative economics of forage crop production on cultivator fields

(Ram Asray Singh)

1. Studies on the relative economics of the year-round fodder production under demonstration trials through improved technology as compared to the crops (forage or other) grown by the farmers including the following crop rotations in overlapping system

(i) Berseem+Mustard — Hybrid Napier + Cowpea

(ii) Berseem + Mustard — Setaria Sphacelata + Cowpea.

For summer 1984 season, the forage crop cowpea+napier and cowpea+Setaria Sphacelata under demonstration yielded on average 203.48+459.65 q/ha and 202.44+453.65 q/ha of green forage with a cost of production of Rs. 1188.76+2036.03 and Rs. 1208.38+2037.02 per hectare and net profit of Rs. 2880.64+4858.85 and 2840.51+4767.80/ha, at prevailing market price (Rs. 20.00/q) for cowpea fodder and Rs. 15.00/q. of napier and Setaria grass. The average input/output worked out to be 1:3.40 and 1:3.34 respectively for cowpea+hybrid napier and cowpea+S. sphacelata.

In demonstration trials, green forage yield of cowpea+hybrid napier and S. sphacelata ranged from 192.35 to 221.68, 456.70 to 461.63 and 430.77 to 476.54 q/ha respectively. The input-output ratio varied from 1:2.93 to 1:4.40 for the forage crop combinations. In all demonstration trials the average cost of production of per quintal green fodder were Rs. 5.90+4.43 and 5.96+4.47 and minimum cost of production was Rs. 4.54+3.41 per quintal of green forage cowpea+hybrid napier. The input–output ratio was 1:4.40.

The return obtained from “Arvi” by the farmer’s was Rs. 12880.37/ha against Rs. 4767.80/ha under the demonstration crop of cowpea+Setaria sphacelata. The input-output ratio were 1:2.31 and 1:3.4 under corresponding systems of cropping. The yield of “Arvi” was 188.57 q/ha with a cost of production of Rs. 9842.31/ha.

In the case of moong crop grown by the farmers the grain yield of moong ranged from 6.56 to 7.35 q/ha with corresponding average input-output ratio of 1:1.23. The maximum net profit was Rs. 986.77/ha and minimum net profit was 571.53/ha. The average cost of production was Rs. 2183.02/ha and the cost per quintal of moong grain worked to be Rs. 288.54. The cost of production of moong bhoosa was Rs. 28.58 per quintal.
1.5 Economics of dairy units in rural and urban areas of Gwalior district (M. P.)

(A. K. Sharma)

1. Analysis of Fixed Assets of dairy units:

Analysis of different components of fixed expenditure indicated that in the dairy units urban area, livestock cost was the major component in investment, accounting for 68.19% of total investment. This was followed by farm building and other structures (20.30%), cattleshed (9.84%) and farm machinery and equipment (1.67%). In case of rural dairy units the corresponding percentage of above items was 46.57%, 37.13%, 14.12% and 2.24%, respectively, while in semi-urban units, farm building and other structures accounted for major share (46.68%) followed by livestock (39.13%), cattleshed (13.10%), farm building and equipment (10.9%).

2. Milk production and cost of milk production:

The average dairy milk yield in urban and semi-urban units was 6.85 kg and 6.99 kg, respectively which was higher than of rural units (4.30 kg). Seasonwise average dairy milk yield was lowest in summer season and highest in winter season in each area. The average dairy milk yield was calculated 6.04 kg. The cost of production was highest (Rs. 2.87) per litre in case of rural units, followed by urban units (Rs. 2.19) and semi-urban units (2.15).

3. Expenditure on milk production and its components:

Feed was the major item of expenditure on milk production, accounting for 43% to 69% with an average of 59.85% of total expenditure. The feed cost was lower in semi-urban and rural areas, where fodder based feeding was practised. Labour was the second important component of cost, accounting for 12% to 24% with an average of 19% of total expenditure. The expenditure on fixed cost varied from 9% to 20% with an average of 15.23% of total expenses, whereas miscellaneous recurring expenditure varied from 4.79% to 6.79% of total expenses.

4. Role of green fodder versus crop residues and concentrates:

In summer season, maximum expenditure (60% to 67%) was incurred on concentrates, followed by dry fodder in semi-urban and urban area. In case of rural dairy units, expendi-
ture on dry fodder was more (58%) as compared to concentrates (42%). Green fodder was not fed to animals in summer season due to its non-availability. In rainy season, expenses on green fodder was incurred and occupied (25.5% to 33.6%) of total expenditure, especially in rural dairy units.

1.6. Marketing of milk and milk product in Babina Block of Jhansi district

(Mallayya)

The study was undertaken on selected dairy farmers in four villages viz., Ganesh Pura, Rundabalora, Dangriarund and Pura of Babina Block. The total milk of selected villages of dairy farmers was 67.53 litres giving an average of 16.86 litre. The cost of milk production per litre was found to Rs 2.30. The input-output ratio of milk production was 1:2.05 and the cost benefit ratio 1:1.05, which was found very much favourable. Similarly, the cost benefit ratio of curd was found to be 1:0.48.

REB-2: BIOMETRICAL STUDIES IN FORAGE PRODUCTION AND UTILIZATION.

2.1. Uniformity Trial on Stylo:

(D. P. Handa)

In the uniformity trial on Stylo it has been found out that equation $Y = aX^{-b}$ gave good fit to the underlying relationship between the average percentage coefficient of variation with blocking and 98.80% without blocking. However, when the same equation was fitted, taking individual C.V. and not the average, gave more or less the same estimate for constant and within the limit for the varying number of observations for different sizes. The fit was good only for the case where no blocking was adopted explaining 77.47% variation. In case of blocking this relation explained 46% to 71%. This could be attributed due to the fact that C.V. values varied highly for a different plot shape for given plot sizes when blocking was adopted indicating that plot shape was important factor to reckoned with, when blocking is adopted. The coefficient of heterogeneity between plots as measured by 'b' coefficient of Smith's equation was low and varied between 0.1872 and 2.135 when blocking was adopted and 0.2377 without blocking. This indicated high positive corelations existed between neighbouring plots. For both fitting of smith law the value of coefficient 'a' was...
highest when no blocking was done (30.18) and (29.96) and was lower but increase with the increase in block size 19.25% to 25.48% and 20.21% to 26.14. This indicates that block size may be kept to the lowest possible.

2.2. Uniformity trial on natural grasses.

(D. P. Handa, P. R. Sreenath)

The equation $Y = aX^{-b}$, where $Y$ is the coefficient of variation and $X$ the block size (number of plots/blocks) showed that in the plots of size 6 m and shapes 1m x 6m, 2m x 3m, 3m x 2m and 6m x 1m, the relationship gave a good fit to the data explaining 83, 84, 94 and 37% for the average C.V. of block shape. The corresponding variation for individual C.V. values were 47, 73, 70 and 37% respectively. This showed that shape of blocks as in plots affected specially the long and narrow plots than square or nearly square plots.

2.3. Rainfall pattern and their role in forage production. Rainfall deficiency in Banda district.

(D. P. Handa)

Drought study were done on the weekly and monthly basis. The weekly data consisted of the period from 1958 to 1977 with seven years data missing. It was found that maximum droughts were observed in june followed by september which accounted to be 47.5% and 42.3% of the total weeks and that too the latter half of the month period of September was having more frequency of drought than the first half which warned that availability of moisture for the rabi crop would be inadequate. The probability of occurrence of drought in first week of June and 3rd week of September was high whereas it was minimum in July and August being the monsoon months. The probability of occurrence of once drought during June and September were 3rd and 4th years while chances of occurrence in July and August was 20 and 9 years, respectively.

Drought study at Jalaun : The weekly drought study at jalaun indicated that maximum drought occurred in the month of June and September which accounted for 58.35% and 56% of their respective week numbers. It has been further observed that first two weeks of June and last two “weeks of September accounted more frequency of drought. Average percentage of drought were 46.41% of the total weeks during the four months.
2.4. Pattern of occurrence of rainfall.

(D. P. Handa, Inder Singh)

The daily rainfall data for the period of 12 years (1971–82) of Jhansi were analysed to get the knowledge of number of wet and dry days and expected length of wet and dry runs which is very useful for the purpose of crop planning as well as in opening the various crop operations. The unit size were one day, two day, three days and four days. When the unit size was more than one day, the criteria of classifying a unit as a dry or wet changed from 3 mm rainfall to number of days in the unit multiplied by 3 mm. At Jhansi in one day unit, dry run varied from 3.25 unit to 7 unit with an average of 4.85 units, in 2 days unit size, dry run varied from 2.28 unit to 4.87 units with an average of 3.66 units while in 3 days units, it varied from 1.61 to 5.75 units with an average of 2.43 and in 4 days unit size varied from 1.62 to 8 units with an average of 3.32 units. It was found that as the size of unit increased, the average dry run decreased up to 3 units size and afterwards increased. In case at wet runs as the size increased, the average wet run increased from 2.16 units of one day size to 3.11 units of 4 days size. It showed that we can expect 3 continuous months in which total rainfall would be equal to or more than 12 mm. The dry wet cycle for one day is 7.0, 2 days size was 5.93, three day size was 5.00 and 4 day size was 6.44. This indicated that as the size increased dry wet cycle decreased.
DIVISION OF EXTENSION AND TRAINING

Ag. Ext-I: ADOPTION AND DIFFUSION OF FODDER INNOVATIONS FEED-BACK INFORMATION.

1.1 Studies on factors (Socio-economic psychological and communication) associated with adoption behaviour of Bundelkhand farmers.

(M. R. Lokhande and Dalaur Singh)

Data in relation to irrigation potentiality, cropping intensity, market orientation and social participation have been collected and analysed. A detailed questionnaire schedule to investigate the objective of the study is under preparation. The study is in progress.

1.2 A study of information source-utilisation patterns of big and small farmers in relation to fodder crops.

(M. R. Lokhande and Maharaj Singh)

The venue of the study is Badagaon and Chirgaon blocks of Jhansi district. Big and small farmers from these two blocks constituted the sample of respondents. Basic information about the villages and the respondent has been gathered from the block offices.

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1.3 **Attitude of small and marginal farmers on adoption of fodder crops in Jhansi district.**

(Maharaj Singh)

The data collection work from the selected respondents have been completed. The analysis of the data will be undertaken soon.

1.4 **Prediction of growing needs of Bundelkhand farmers with special reference to forage production at their own farms.**

(Dalaur Singh)

The item analysis of different need is in process. The project is in progress.
3.1. Introduction of exotic forage flora for preliminary evaluation.

(B. K. Misri)

Forty six exotic collections of *Lotus, Trigonella, Trifolium, Melilotus* and *Ervilia* received during 1984 were sown. Out of these, only *Ervilia* germinated. The evaluation of this plant revealed that the average height attained was up to 10 cm, the foliage was very little and the plant was unsuitable for use as a forage species.

3.6. Introduction of indigenous forage flora for preliminary evaluation.

(B. K. Misri)

To explore the possibility of introducing short duration crops as winter fodders in Kashmir, 34 collections of barley and 14 collections of wheat collected from Ladakh region were evaluated at IGFRI substation, Manasbal. Wide range of variation was observed in barley for days to 50% flowering (157-183), no. of tillers per metre row (49-252), plant height (52.4–82.1 cm) green fodder yield (54.6–355.3 q/ha), dry matter yield (16.0–121.3 q/ha) and
grain yield (6.6–34.6 q/ha). Cultivars with specific desirable traits, viz., SSL-120, 239, 240, 245, 246, 251 and 254 for earliness, SSL-92, 113, 120 for high tillering, SSL-158, 187 for tallness, SSL-109, 184, 247 for high green and dry matter yield and SSL-131, 187, 237, 241, 247 for high grain yield, were identified for further exploitation. In wheat, the range of variation observed was 184–208 for days to 50% flowering, 153–197 for tillers per meter row, 82.0–245.3 q/ha for green fodder yield, 22.6–70.0 q/ha for dry matter yield and 3.3–24.6 q/ha for grain yield. The specific desirable cultivars, viz, SSL-196, 188, 181, 161 for early flowering, SSL-167, 188 for high tillering, SSL-154 for tallness, SSL-47, 154, 166, 188 for green and dry matter yield and SSL-188, 196 for high grain yield were selected for further use.

3.7. Evaluation of different cultivars of oats in temperate region.

(B. K. Misri, R. N. Choubey and S. K. Gupta)

Five strains of oats developed at IGFRI, were evaluated in a replicated trial with kent as check at three different sites. The performance of these strains (table-45) revealed that JHO-810 produced significantly higher yield than kent in all the three sites. Thus, JHO-810 appeared to be the most suitable strain in Kashmir valley.

SST-7 : INTENSIFICATION OF FODDER CULTIVATION DURING WINTER IN PADDY FALLOW AND OTHER AVAILABLE SITES IN TEMPERATE REGIONS.

7.4. Cultivation of turnips as a multi-cut gap crop during winter.

(B. K. Misri)

During third year of experiment, it has been established from the data (table-46) that turnips can be grown as a multi-cut fodder crop and is suitable for giving fodder at a time when no other green material is available for feeding the livestock.
Table-45: Average green and dry matter yield of various oat genotypes at three locations in Kashmir valley.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>GFY (q/ha)</th>
<th>DMY (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L₁</td>
<td>L₂</td>
</tr>
<tr>
<td>JHO-801</td>
<td>154.6</td>
<td>193.6</td>
</tr>
<tr>
<td>JHO-802</td>
<td>226.0</td>
<td>212.0</td>
</tr>
<tr>
<td>JHO-810</td>
<td>296.0</td>
<td>262.6</td>
</tr>
<tr>
<td>JHO-815</td>
<td>169.3</td>
<td>253.3</td>
</tr>
<tr>
<td>JHO-819</td>
<td>189.3</td>
<td>192.0</td>
</tr>
<tr>
<td>Kent</td>
<td>158.0</td>
<td>149.3</td>
</tr>
<tr>
<td>C. D. (5%)</td>
<td>50.2</td>
<td>68.1</td>
</tr>
</tbody>
</table>

L₁ = IGFRI Sub-Station Farm, Marasbal.

L₂ = Rice field, Village Asham.

L₃ = Botanical Garden, University of Kashmir.
Table-46: Production potential of tubers and foliage in turnips

<table>
<thead>
<tr>
<th>Fertilizer treatment (q/ha)</th>
<th>Foliage yield (q/ha)</th>
<th>Yield of tuber + foliage 10th Dec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st cut</td>
<td>II cut</td>
</tr>
<tr>
<td>60 N+60 P</td>
<td>305.0</td>
<td>109.0</td>
</tr>
<tr>
<td>40 N+40 P</td>
<td>219.0</td>
<td>18.0</td>
</tr>
<tr>
<td>20 N+20 P</td>
<td>183.0</td>
<td>12.5</td>
</tr>
</tbody>
</table>
PUBLICATIONS

1 Papers Published


9. Deb Roy, R. A selected and annotated bibliography with special reference to silvipasture and forest grazing. Ibid.


32. Handa, D. P., Sreenath, P. R., Rajpali, S. K. and Shri Ram. Size and shape of plots and stocks for experiment with natural grasses.


(226)


82. Zadoo, S. N. Induced chromosomal interchanges in *Sesbania aegyptica—cytolagia* (In press).

( 229 )
83. Zadoo, S. N. Chromosomal stability in induced tetraploid of *Atylosia scarabaeoides* *Curr. Sci.* (In press)


Papers Presented in workshops/seminars/symposia.


15. Hazra, C. R. Role of Su-babool in Agroforestry production system for the training programme on “Alternate Land Use System” from 7-10 January, 1985 at CRIDA, Hyderabad.


18. Hazra, C. R. Delivered lecture on 8-5-85 at IGFRI, Jhansi on the Summer Institute on “Recent advances on Forage breeding for farming systems”. The topic of the lecture was on Relative performance of fodder crops and trees under agroforestry system of forage production.


30. Tripathi, S. B. and Hazra, C. R. Forage production and nutrient uptake by berseem as influenced by P and M₀ application in calcareous soil.


**Research Bulletin : Popular Articles**


APPENDIX—I

LIST OF STAFF

(as on 31, December, 1985)

Director:

B. D. Patil, Ph D. (upto 15th July, 1985)
T. R. Dutta, Ph. D. (16th July, 1985 onwards)

I. Scientific

Division of Plant Improvement:

R. B. R. Yadav, Ph. D., S-3 (Plant Physiology) & Head of Division
Bhag Mal, Ph. D., S-3 (Plant Breeding)
S. R. Gupta, Ph. D., S-3 (Economic Botany)
S. T. Ahmed, Ph. D., S-2 (Plant pathology)
C. B. Singh, M. Sc., S-2 (Plant Breeding)
S. K. Gupta, Ph., D., S-2 (Plant Breeding)
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S. N. Zadoo, Ph. D., S-2 (Genetics & Cytogenetics)
S. N. Tripathi, Ph. D., S-2 (Genetics & Cytogenetics)
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O. P. Dixit, M. Sc., S-1 (Plant Breeding)
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U. S. Mishra, M. Sc., S-1 (Plant Breeding)
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H. K. Joshi, M. Sc., S-1 (Plant Pathology)
O. P. S. Verma, M. Sc., S-1 (Plant Physiology)
J. N. Gupta, Ph. D., S-1 (Economic Botany)
U. P. Singh, M. Sc., S-1 (Economic Botany)

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Menhi Lal, Ph. D., S-3 (Agronomy)
Shivaji Prasad, Ph. D., S-3 (Agronomy) (Resigned on 30-8-85)
N. P. Shukla, M. Sc., S-2 (Agronomy)
Fateh Singh, M. Sc., S-2 (Agronomy)
M. S. Raut, M. Sc., S-1 (Agronomy)
S. N. Tripathi, M. Sc., S-2 (Agronomy)

Division of Soil Science:

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N. D. Mannikar, Ph. D., S-4 (Soil Science) (Transferred on 15-11-85)
C. R. Rawat, M. Sc., S-2 (Agronomy)
Dashrath Singh, Ph. D., S-2 (Soil Science)
M. R. Pahwa, Ph. D., S-2 (Soil Microbiology)
R. K. Tyagi, Ph. D., S-2 (Geography)
O. P. S. Panwar, M. Sc., S-2 (Soil Science)
S. B. Tripathi, M. Sc., S-1 (Soil Science)
I. Y. L. N. Murthy, M. Sc., S-1 (Agriculture Chemistry)
Mrs. N. Kewalramani, Ph. D., S-1 (Animal Nutrition)
Pradeep Behari, M. Sc., S-1 (Physics)

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B. K. Trivedi, Ph. D., S-2 (Economic Botany)
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K. A. Singh, M. Sc., S-2 (Agronomy)
G. K. Dwivedi, M. Sc., S-1 (Agronomy)
S. S. Parihar, M. Sc., S-1 (Economic Botany)

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D. S. Chauhan, Ph. D., S-3 (Agronomy)
V. K. Gupta, Ph. D., S-2 (Plant Breeding)
M. M. Roy, M. Sc., S-1 (Economic Botany)
S. K. Gupta, M. Sc., S-1 (Economic Botany)
T. A. Khan, M. Sc., S-1 (Statistics)

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P. S. Tomar, S-4 (Agronomy)
Shree Ram, Ph. D., S-3 (Entomology)
R. K. Pandey, Ph. D., S-3 (Agronomy)
O. P. Singh, Ph. D. S-2 (Agronomy)

( iii )
Division of Plant Animal Relationship

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A. Rekib, Ph. D., S-4 (Animal Nutrition)
V. C. Pachauri, Ph. D., S-3 (Animal Nutrition)
P. Kumar, Ph. D., S-3 (Animal Nutrition)
A. P. Singh, Ph. D., S-3 (Agriculture Chemistry)
S. C. Gupta, M. Sc., S-2 (Analytical Chemistry)
V. S. Upadhyay, M. Sc., S-2 (LPM)
J. P. Varshney, M. V. Sc., S-2 (Veterinary Medicine)
N. C. Verma, M. Sc., S-2 (LPM)
A. B. Majumdar, M. Sc., S-2 (Bio Chemistry)
S. Rangaswami, M. Sc., S-1 (Organic Chemistry)
L. K. Karnani, M. Sc., S-1 (Agriculture Chemistry)
K. S. Ramachandra, Ph. D., S-1 (Animal Nutrition)
J. N. Sebastien, M. Sc., S-1 (Organic Chemistry)
B. K. Bhadoria, M. Sc., S-1 (Organic Chemistry)

Division of Agricultural Engineering

Jai Singh, Ph. D., S-4 (Agriculture St. & Proc. Engg.)
R. B. Vershney, B. Tech., S-2 (Soil Water Engg.)
Division of Rural Economics and Biometrics

D. P. Handa, M. A., S-2 (Stat.) & Head of Division
P. R. Sreenath, M. A., Dip. Agriculture Stat. S-3 (Statistics)
I. P. S. Yadav, M. Sc., S-2 (Economics)
Mallayaswami, M. A., S-1 (Economics)
A. K. Sharam, M. A., S-1 (Economics)
Ram Ashrey Singh, M. A., S-1 (Economics)
Ashok Kumar, M. Sc., S-1 (Statistics)
R. M. Sood M. Sc., S-0 (Statistics)
Inder Singh, M. Sc., S-0 (Statistics)

Division of Extension

M. R. Lokhande, Ph. D., S-3 (Extn.) & Head of Division
W. L. Barwad, M. Sc., S-2 (Entomology)
H. L. Gazbhie, M. Sc., S-2 (Entomology)
Dalaur Singh, M. Sc., S-1 (Extn);
Maharaj Singh, M. Sc., S-1 (Extn)

Forage Project

Khubi Singh, M. A., S-1 (Statistics)
S. D. Gupta, M. Sc., (Ag) S-0 (Agronomy)

Sub-Station Manasbal (J & K)

B. K. Misri, Ph. D., S-2 (Economic Botany) & I/e Sub-Station

II. Technical

A. K. Srivastava, Technical Oficer (T-6)
M. M. Rastogi, Assistant Librarian (T-5)
C. B. Mishra, Photographer-cum-Artist (T-5)
H. B. Dhingra, Land Surveyor (T-5)
S. K. Rajpali, Sr. Technical Assistant (T-5)
Mahavir Singh, Farm Assistant (T-5)
N. C. Srivas, Lab. Asstt. (T-5)
R. B. Mathur (T-4)
D. K. Bhutani (T-4)
Shree Ram Sikanya (T-4)
C. P. Gupta (T-4)
Mahipal Singh (T-4)
Ravindra Pal Singh (T-4)

III. Administrative

A. S. Bhati, Administrative Officer transferred to I.V.R.I on september 1985
J. K. Kewalramani, Administrative Officer
A. Ramadas, Accounts officer
Shri L. S. Sharma, Superintendent
Shri Gauri Shankar, Superintendent
Shri Veer Singh Superintendent
Shri S. N. Dubey Superintendent
R. S. Chauhan, Superintendent

IV. Auxilliary

V. K. Litoria, Jr. Medical Officer
Statement showing the total number of employees in the Institute and the number of Scheduled Castes/Scheduled Tribes amongst them as on 31st July, 1985.

<table>
<thead>
<tr>
<th>S. No, Class of posts</th>
<th>Total number of Posts sanctioned (Viable)</th>
<th>Total number of employees in position.</th>
<th>Total number of S/C among them</th>
<th>Total number of S/T among them</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scientific posts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientist S-0</td>
<td>92</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Scientist S-1</td>
<td>85</td>
<td>53</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Scientist S-2</td>
<td>47</td>
<td>36</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Scientist S-3</td>
<td>14</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. Technical posts:</td>
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<td></td>
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<tr>
<td>Category I</td>
<td>74</td>
<td>29</td>
<td>9</td>
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<tr>
<td>Category II</td>
<td>63</td>
<td>27</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Category III</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>3. Administrative posts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAO/AO/Accounts Officer</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AAO/Supdt/Supt (A&amp;A)</td>
<td>9</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Assistant</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Stenographers (Sr. and Jr.)</td>
<td>15</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Senior Clerks</td>
<td>27</td>
<td>24</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Junior Clerks</td>
<td>17</td>
<td>14</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>4. Supporting staff</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade IV</td>
<td>7</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Grade III</td>
<td>13</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Grade II</td>
<td>27</td>
<td>22</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Grade I</td>
<td>119</td>
<td>74</td>
<td>36</td>
<td>-</td>
</tr>
<tr>
<td>Supporting staff (Safaiwala)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>5. Auxiliary posts</td>
<td>38</td>
<td>17</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

(vii)
# APPENDIX-II

## Statement Showing head-wise Expenditure during 1985–86

<table>
<thead>
<tr>
<th>Description</th>
<th>NON PLAN (in Rs)</th>
<th>PLAN (in Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pay and Allowances</td>
<td>74,10,700</td>
<td>14,800</td>
</tr>
<tr>
<td>2. T. A.</td>
<td>1,45,800</td>
<td>30,200</td>
</tr>
<tr>
<td>3. Recurring Contingencies</td>
<td>16,10,900</td>
<td>9,89,400</td>
</tr>
<tr>
<td>4. Recurring Contingencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. (i) Workes</td>
<td></td>
<td>4,13,500</td>
</tr>
<tr>
<td>(ii) Equipment</td>
<td>66,400</td>
<td>17,500</td>
</tr>
<tr>
<td>(iii) Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(iv) Others</td>
<td>1,63,500</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>93,94,300</strong></td>
<td><strong>14,65,400</strong></td>
</tr>
</tbody>
</table>

(viii)