REVIEW OF LITERATURE
This chapter presents a comprehensive review of the available literature on the comparative performance of *Pennisetum pedicellatum* varieties and their response to nitrogen nutrition in pure stand as well as intercropped with cowpea or clusterbean in terms of growth characters, forage yield and quality traits. The key issues on its amplitude of adaptability, compatibility with forage legumes for nutritional quality and nitrogen economy have also been covered in this section.

**Environmental Adaptability of Dinanath Grass:**

The grasses have wide range of variability with respect to type of growth, response to different methods of management, breeding behaviour, edaphic adaptation and other important characteristics (Musser *et al.*, 1948). The name of genus *Pennisetum* is derived from the Latin word "Penna" feather and "Seta" a bristle and the species *pedicellatum* represents having a small stalk of spikelets. The origin of this grass seems to be India. Its occurrence is reported in the hills of Chhotanagpur, Bihar (Haines, 1924), hills of Bihar, Rajputana, Orissa and Western peninsula (Blater and McCann, 1935) and Madhya Pradesh (Khan, 1957). *Pennisetum pedicellatum* grass is known by different names like "Dinanath", Deenbandhu", Deena” and Dinagrass. A number of ecotypes were isolated in India from the seed samples obtained from Nigeria (Chatterjee and Kumar, 1964).
Its fodder value was first recognized in Australia (Oyenuga, 1957). In India, it is considered as a good forage crop in the states of Assam (Mukherjee, 1969-70), West Bengal (Chatterjee et al., 1973), Bihar (Mukherjee and Chatterjee, 1955), Uttar Pradesh (IGFRI, 1972), Punjab (PAU, 1970), Haryana (Singh and Arora, 1970; Relwani and Bagga, 1968), Orissa (Mandal and Vamadevan, 1978; 1983), Maharashtra (Desai and Deore, 1977) and Madhya Pradesh (Khan, 1957). The species was claimed to be a palatable forage grass grazed by sheep, goats and cattle (Chatterjee and Das 1989).

Dinanath grass is a high yielding, quick growing, luscious, leafy and thin stemmed grass. As a high yielding short duration grass it fits well in cropping systems between two arable crops. In case of monocropping of Dinanath grass usually one cut is taken after 80-90 days of sowing and then the crop is left for seed production.

Systematic research on this grass was initiated at Sabor Agricultural College, Bihar in 1953 (Mandal and Chatterjee, 1953; Chatterjee et al., 1954). In India, Chatterjee and Richharia (1955) were the earliest workers to investigate agronomical and ecotypic differences in *Pennisetum pedicellatum*. The plant type and their growth characters were further elaborated by Mukherjee and Prasad (1958), Sharma (1966), Chatterjee and Pillai (1970), Chatterjee and Reddy (1975) and Patil and Ghosh (1959-63).
Dinanath grass prefers a good moist soil during its active growth period. However, it also grows well in eroded marginal wastelands, banks of marshy areas and poor soils but gives much higher yields on fertile well-drained loams receiving annual rainfall of 500 to 1500 mm. The grass is not suitable for flood prone areas and cold temperate regions. The grass grows well both in acidic as well as sodic soils. Dinanath grass can be grown in acidic soil without liming. It can also tolerate soil salinity of 12 mmhos/cm and soil pH ranging from 5.5 to 8.0 (IGFRI, 1984).

Dinanath grass has acquired a special place amongst kharif forages in many parts of the country. High tonnage, low water requirement, resistant to diseases and pests, good seed setting with no damage by birds are some of the points which go in favour of this grass (Bose, 1965; Chatterjee and Singh, 1967; Relwani and Bagga, 1968; Rathore and Kumar, 1977).

Bose (1965) reported that in sandy soil of Dumaraon (Bihar) Dinanath grass outyielded pearl millet recognized as promising crop of the locality. Singh and Arora (1970) recorded green forage yield of Dinanath grass as high as 800-1000 q/ha against 200-470 q/ha yield from maize, sorghum and pearl millet at Hissar. The yield levels of Dinanath grass in terms of green forage have been reported to be 1000 q/ha in West Bengal (Mukherjee et al., 1976) and up to 1285 q/ha in Orissa (Mandal and Vamadevan, 1978). One more selected strain (T-15) of Dinanath grass significantly outyielded (700-800 q/ha) some of
the high yielding forages like jowar (300-400 q/ha) in green
forage production (Singh, 1982).

Comparative Performance of *Pennisetum pedicellatum*
Varieties:

Growth behaviour and forage yield: The varietal trials on
*Pennisetum pedicellatum* conducted at various centres under All
India Coordinated Research Project on Forage Crops in the last
one decade provided very useful experimental evidence on their

In 1981-82, significant variation in plant height was
observed at Hissar and Rahuri but not at Jorhat. However,
varieties did not differ significantly in number of tillers at
any location in 1981. Variety Bundel-1 produced more leaf than
other varieties. IGFRI-3808 and Bundel-1 produced highest green
forage yield of 153.7 and 446.0 q/ha at Anand and Hissar,
respectively. The corresponding dry forage yields were 29.2 and
104.4 q/ha.

In 1982-83, variety Bundel-1 ranked second in plant height
at Rahuri. Significant variation in green forage yield was
recorded at Uruilikanchan, Rahuri, Hyderabad and Jhansi. Variety
Bundel-1 at Rahuri gave the highest green forage yield. The
overall mean of the centre showed that variety Bundel-1 ranked
third in green forage production. In case of dry matter, the
differences were significant at Uruilikanchan and Rahuri and not
at Jhansi.
In 1983-84, at Urulikanchan variety Bundel-2 produced tallest plant of 200.1 cm whereas, JP-1 resulted in shortest plant of 152.3 cm. However, Bundel-1 and IGFRI-3808 produced plant height of 160.5 and 179.3 cm, respectively. Variety IGFRI-3808 produced 117.7 tillers per metre row length followed by Bundel-1 (89.0 tillers) and Bundel-2 (76.7 tillers) per metre length at Urulikanchan. The data on number of days taken to attain 50 % flowering at Urulikanchan was 89 days for Bundel-1, 85 days for IGFRI-3808 and 82 days for Bundel-2.

Significantly higher dry matter yield was recorded with variety IGFRI-S-4-1-2 (177.2 q/ha) followed by Bundel-2 (174.6 q/ha). Bundel-1 producing 133.8 q/ha dry matter was statistically at par with variety IGFRI-3808 (145.9 q/ha).

In 1984-85, at Rahuri variety IGFRI-S-2-2-2 ranked first (250.6 cm) in plant height followed by Bundel-1 (190.0 cm) and Bundel-2 (185.6 cm). Variety IGFRI-3808 produced plant height of 143.0 cm. At Jabalpur variety Bundel-2 ranked first (241.0 cm) in plant height, whereas, variety IGFRI-3808 ranked 5th (204.0 cm) and Bundel-1, 10th (123.0 cm). The highest leaf:stem ratio occurred with variety IGFRI-S-4-1-2 followed by IGFRI-S-32-1. Variety Bundel-1 gave lowest leaf:stem ratio. Varieties IGFRI-3808 and Bundel-2 showed almost similar leaf:stem ratio (0.44 and 0.42). Variety Bundel-1 took 88 days in attaining 50 % flowering stage whereas, varieties Bundel-2 and IGFRI-3808 took only 80 days at Jabalpur. The dry matter yields of variety Bundel-2 (71.8
q/ha), IGFRI-3808 (71.7 q/ha) and Bundel-1(70.3 q/ha) were at par but significantly higher than JP-13 (46.2 q/ha), IGFRI-S-56-1 (45.5 q/ha) and JP-1 (39.2 q/ha). Green forage yield of different varieties did not differ significantly at any location of central zone. However, on the basis of pooled data Bundel-1 produced higher green forage yield of 212.4 q/ha as compared to Bundel-2 (209.4 q/ha) and IGFRI-3808 (190.8 q/ha). In case of dry forage production, Bundel-2 outyielded IGFRI-3808 and Bundel-1.

In 1985-86, variety Bundel-2 ranked second in plant height at Rahuri. Variety Bundel-1 and IGFRI-3808 produced similar (96.7) number of tillers per running metre. Variety Bundel-1 took 95 days in attaining 50% flowering stage whereas, variety IGFRI-3808 took only 82 days. Variety Bundel-1 ranked 2nd in leaf:stem ratio (0.36) and minimum leaf:stem ratio (0.20) occurred with IGFRI-S-2734. In green forage production, variety Bundel-2 performed better and ranked third at Rahuri, Bundel-1 performed better at Urulikanchan and ranked third. IGFRI-3808 ranked second at Jabalpur but scored first over the centres. In case of dry matter yields, varieties differed significantly at Rahuri and Jabalpur and not at Urulikanchan. Bundel-2 ranked third at Urulikanchan, Bundel-1 ranked fifth at Urulikanchan and Rahuri and IGFRI-3808 ranked third at Jabalpur. Variety IGFRI-3808 registered significantly highest crude protein yield (15.6 q/ha) and excelled out IGFRI-S-56-1, IGFRI-S-2734 and IGFRI-S-31-1. On the basis of pooled data over the centres variety Bundel-2
produced highest crude protein yield (10.2 q/ha) followed by Bundel-1 (8.9 q/ha).

In 1986-87, variety Bundel-1 produced highest green forage yield at Rahuri. Bundel-2 produced highest green forage at Jhansi followed by Bundel-1. On the basis of pooled data over the zones, Bundel-2 ranked second in green forage production. However, varieties differed significantly in green forage production at Rahuri, Jhansi and Jabalpur and not at Akola and Urulikanchan. In case of dry forage, variety Bundel-2 produced highest yield at Jhansi, Akola and Jabalpur. On the basis of pooled data over the zones, variety Bundel-2 ranked second in dry forage production. The highest crude protein yield was recorded with IGFRI-S-2-2-2 followed by Bundel-2 (13.8 q/ha) at Urulikanchan and by Bundel-1 (8.7 q/ha) at Rahuri. The data averaged over the locations in 1986-87 produced crude protein yields in order of IGFRI-S-2-2-2 > IGFRI-S-56-1 > Bundel-2 > Bundel-1.

In 1987-88, at Jabalpur, variety Bundel-1 recorded tallest plant of 162.2 cm followed by JP-13 (159.3 cm). Maximum leaf:stem ratio was obtained with Bundel-2 followed by IGFRI-S-56-1. Variety Bundel-1 produced significantly highest green forage yield at Jabalpur. On the basis of pooled data over the zones, Bundel-2 ranked second in green forage as well as dry matter production. Variety Bundel-2 produced significantly higher crude protein yield (4.6 q/ha) as compared to Bundel-1 (3.9 q/ha).
Advanced varietal trials on Dinanath grass with nine entries in 1988-89 revealed that Bundel-2 produced tallest plants. Varieties Bundel-1, BDN-1 and TNDN-1 were observed to be late flowering. Variety JHP-2 produced highest green forage yield as compared to other entries including Bundel-1 and Bundel-2 in all the zones and on all India basis. In terms of dry matter production, variety Bundel-2 (174.6 q/ha) proved significantly superior over Bundel-1 (138.8 q/ha) which in turn did not differ significantly from IGFRI-3808 (145.9 q/ha). In crude protein yield, variety Bundel-2 ranked second. Moreover, variety JHP-1, JHP-2 and Bundel-2 had high neutral detergent fibre (NDF) content than other entries.

Chemical composition and quality traits: Singh and Arora (1970) reported that Dinanath is relished by animals just like sorghum. The chemical composition of the grass on dry matter basis at flowering stage is as 6.5 % crude protein, 3.2 % ether extract, 35.8 % crude fibre, 40.1 % nitrogen free extract, 14.4 % total ash, 85.7 % organic matter, 0.4 % calcium and 0.3 % phosphorus.

The crude protein content of Dinanath grass is equivalent to sorghum and other graminaceous forages of kharif season harvested at flowering stage. The crude protein content ranged from 3.5 to 6 % in 12 genotypes of Pennisetum pedicellatum harvested at 95 days of growth (Das and Arora, 1976). However, a range of 6-10 per cent crude protein has been reported at preflowering to flowering stage (Bose, 1965; Singh and Arora, 1970; Das et al., 1974; Pal et al., 1975).
The most notable feature of the grass is its low content of oxalic acid, i.e., 1.7 % against 2.5 % in bajra and 6.0 % in Napier grass. In Assam, Mukherjee (1970) recorded 0.42 kg of digestible protein and 3.55 kg of starch equivalent in 45.35 kg of green forage. Feeding of this grass to local bullocks ensured highly positive nitrogen balance and satisfactory phosphorus retention but calcium balance was slightly negative. Banerjee et al. (1973) recorded slightly negative nitrogen balance and marginally positive calcium balance in black Bengal goat.

Upadhyay et al. (1978) reported that the digestibility of dry matter, organic matter and nitrogen free extract of Dinanath grass was satisfactory in Barbari goats. Nutrient balance study indicated that there was negative balance of nitrogen and phosphorus and positive balance of calcium.

Digestibility of crude protein, ether extract, crude fibre, nitrogen free extract, dry matter, organic matter, digestible crude protein and total digestible nutrients were 48.5, 43.5, 71.1, 59.0, 59.5, 63.3, 2.9 and 58.6 per cent, respectively.

Oyenuga (1957) and Paul et al. (1981) reported the superior nutritive value of the grass. They analysed the grass for proximate constituents at different stages of growth and found that its crude protein percentage was high and the rate of deterioration of digestibility appeared to be greater than perennial grasses, i.e., Napier, Rhodes grass etc.

The chemical composition and physical properties of Dinanath grass vary with stages of crop growth. Protein content decreased
whereas, structural carbohydrate increased with age. Neutral
detergent fibre (NDF), acid detergent fibre (ADF) and lignin were
negatively correlated with invitro dry matter digestibility
(Johri et al., 1975; Paul et al., 1981; Das and Arora, 1976).

The digestibility co-efficients for organic matter and crude
protein were reported to be 69-73 and 63-65 per cent, respectively. The hemicellulose and cellulose contents in
Dinanath grass were almost equal to other species of genus
Pennisetum (Das et al., 1978).

Intercropping of Pennisetum pedicellatum with Forage
Legumes:

In the recent past the cereal-legume intercropping is
gaining importance both in temperate and tropical regions of the
world (Searle et al., 1981; McCollium, 1982; Allen and Obura,
1983; Chui and Shibles, 1984). This may be due to some of the
established and speculated advantages of intercropping systems
such as higher grain yields, greater land use efficiency per unit
land area, and improvement in soil fertility through the addition
of nitrogen by fixation and excretion from component legumes
(Agboola and Fayemi, 1972; Willey, 1979; Eaglesham et al., 1981).
The intercropping of legumes with cereals offers scope for
developing energy efficient and sustainable agriculture
(Papendick et al., 1976; IAEA, 1980). In forage farming, the
grass + legume intercropping increases forage yield, improves
herbage quality, reduces the risk of anti-quality constituents
and economises fertilizer nitrogen (Tiwana and Bains, 1976).
Dinanath grass is grown either as a pure crop or in mixture with forage legumes such as cowpea, ricebean and clusterbean. Dinanath grass performs well under mixed cropping in alternate 30 cm apart rows with cowpea or ricebean and thus provides quality forage for dairy cattle (Mukherjee et al., 1982).

Intercropping with legumes provides additional forage besides improving the quality of herbage. The legumes are rich in protein and also improve soil fertility by fixing atmospheric nitrogen varying from 100-200 kg/ha (Ostrowski, 1972).

Growth rhythm and forage yield: Chatterjee et al. (1978) reported that Dinanath grass and legumes yielded green forage of 450 q/ha and 250 q/ha, respectively. The intercropping system provides leafy, succulent, nutritious and palatable forage for longer duration extending up to the scarcity period of October to November in North India.

Das and Chatterjee (1976) found optimum leaf area index of 7.5 in Dinanath grass for intercepting 95 per cent of incident light. At low N level of 20 kg/ha, higher dry matter accumulation was observed up to 80 days in mixed cropping of Dinanath grass + ricebean/cowpea than pure grass.

Investigation by Senthivel et al. (1991) concluded that in pure stand, Dinanath grass produced highest green and dry forage yields. Cowpea in pure stand recorded higher crude protein yield over Dinanath and guar. Dinanath grass and cowpea cross sown at full seed rate registered highest green and dry forage yields as well as crude protein production over other combinations.
Higher forage and crude protein yields under mixed cropping of Dinanath grass + cowpea at full seed rates were also obtained by Tripathi (1989) in rainfed vertisols.

Das and Chatterjee (1977) studied the nature of competition between Dinanath grass and legumes-cowpea/ricebean both in summer and rainy seasons. Summer growth of grass tends to suppress the legumes while during rainy season the viny legumes suppress the grass. They also observed nitrogen economy in forage production through mixed cropping of grass and legumes with 20 kg N/ha and adequate quantity of P and K fertilizers. Eighty days after sowing, Dinanath grass + cowpea yielded as much dry matter as that of pure Dinanath grass obtained with 75–100 kg N/ha in dry season and 25–35 kg N/ha in wet season. The crude protein yield was highest with 160–190 kg N/ha in dry season and with 50–80 kg N/ha in wet season.

The trial conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1984-85 to 1986-87) concluded that in 1984-85 the green and dry forage yields obtained from pure stand of Pennisetum pedicellatum (271.4 q green and 61.5 q dry matter/ha) and with cross sowing Dinanath grass and cowpea (237.6 q green and 54.7 q dry matter/ha) were significantly higher than pure cowpea (58.1 q green and 15.4 q dry matter/ha), Dinanath grass + cowpea in row ratio of 1:1 (152.6 q green and 32.8 q dry matter/ha), 2:2 (205.2 q/ha green forage) and 2:1 (203.9 q green and 46.9 q dry matter/ha). The green forage yield in 2:2 planting pattern was statistically at par with that of
2:1. *Pennisetum pedicellatum* pure as well as in combination with cowpea showed significantly higher green and dry forage yields as compared to cowpea pure. In 1985-86, the highest green and dry forage yields were recorded with cross sowing of Dinanath grass and cowpea at Kanke, Vellayani and Jabalpur, while at Palampur and Coimbatore highest green forage yield was obtained with pure Dinanath grass. In 1986–87, out of seven crop combinations, Dinanath grass + cowpea was found most productive. The trial conducted at Kanke recorded the highest green and dry forage yields with cross sowing of Dinanath grass and cowpea followed by alternate rows of Dinanath grass + cowpea (1:1) and paired rows (2:2) of Dinanath grass + cowpea.

Chatterjee and Roquib (1986) observed that Dinanath grass grown during mid July to mid October gave the highest green forage yield of 45.6 t/ha as compared to maize + cowpea grown during February to March (37.8 t/ha). Prasad (1986) reported that perennial Dinanath grass + *Stylosanthes* mixture proved superior over thin napier grass + *Stylosanthes* for hilly areas of Bihar.

**Nutrient outturn and forage quality:** The mixed cropping of Dinanath grass with cowpea or ricebean in alternate paired rows recorded increased forage yield, higher land equivalent ratio (LER), greater crude protein outturn and fertilizer use efficiency as compared to sole cropping (Tripathi et al., 1984).
Tripathi (1989) also reported higher crude protein yield under mixed cropping systems of sorghum/pearl millet/ Pennisetum pedicellatum with cowpea and guar. Intercropping of Blue panic grass either with cowpea or guar resulted in the highest total crude protein outturn (Singh et al., 1984).

Studies on the effect of fertilizer application and legume introduction on the productivity of Dicanthium annulatum pasture revealed that the maximum dry matter yield of 69.6 q/ha was obtained with 60 kg N + 30 kg P₂O₅/ha followed by the introduction of Stylosanthes hamata fertilized with 30 kg P₂O₅/ha (67.5 q/ha). However, crude protein yield was maximum (5.67 q/ha) with grass + Stylosanthes hamata + 30 kg P₂O₅/ha followed by grass + Macroptelium atropurpureum + 30 kg P₂O₅/ha indicating that Stylosanthes hamata was more suitable for introduction in Dicanthium annulatum as compared to other legumes. The mixed stands, need to be fertilized with 30 kg P₂O₅ per hectare for getting the higher yield of quality forage (Rai, 1988). The beneficial effect of grass-legume mixture over pure stand has also been documented by Chauhan and Faroda (1979) and Rai and Kanodia (1982).

Narwal et al. (1988) reported more green forage yield in mixture of seed of legume and cereal and drilled in same row (22.03 t/ha) and intercropping (21.2 t/ha) as compared to monoculture of soybean (20.07 t/ha), cowpea (18.23 t/ha) and pearl millet (13.05 t/ha). Cowpea + pearl millet mixture gave maximum green forage yield (22.57 t/ha) than other cropping
systems. Crude protein content of pearl millet was increased when sown in mixture (8.18%) and intercropping (8.52%) as compared to its monoculture (7.77%). Likewise, crude protein content of mixed forage grown in mixture (9.19%) and intercropping (11.03%) was greater than that of pure pearl millet fodder (7.77%). However, voluntary dry matter intake, total digestible nutrients, dry matter digestibility and metabolizable energy of mixed fodder were similar when grown in mixture or intercropping systems.

Singh and Singh (1986) on the basis of three years of experimentation on buffel grass (*Cenchrus ciliaris* linn.) found higher crude protein content, *in vitro* dry matter digestibility and lower cell wall constituents when grown as buffel grass + *guar*, buffel grass + cowpea and buffel grass + fodder moth bean than buffel grass + grain clusterbean, buffel grass + grain cowpea, buffel grass + grain moth bean or its pure stand. However, buffel grass + fodder clusterbean and buffel grass + grain moth bean excelled the other cropping systems for crude protein and *in vitro* dry matter digestibility of the buffel grass. Singh, (1983) found that intercropping of cowpea with *anjana* grass increased the forage production of the latter considerably. The lowest crude protein content was recorded with pure *anjana* grass. Maximum crude protein content was recorded with intercropping of cowpea.

Mixed cropping improved the quality of herbage by increasing the protein content (Patel et al., 1973) and reducing the level
of toxic constituents viz., oxalate in Dinanath grass. Tiwana and Bains (1976) also reported reduction in anti-quality factor like oxalic acid due to introduction of leguminous fodder crops in hybrid Napier.

Effect of Nitrogen Nutrition on *Pennisetum pedicellatum*:

Nitrogen is the key element in crop growth and is the most limiting nutrient in Indian soils. The paramount importance of nitrogen for increasing herbage yield has been widely accepted. The major portion of the N taken up by plants is used in synthesizing protein. About 10-30 % of the total N in grasses will be found in non protein N (NPN) form. Tropical grasses have been reported to grow better than their temperate counterpart at low level of N. Nitrogen application not only increases the green and dry matter yields but also influences the quality of forage, particularly the level of protein (Menhi Lal and Tripathi, 1987 a).

Nitrogen exercises favourable effects on growth attributes (plant height and number of leaves), palatability characteristics (leaf:stem ratio), quality parameters (protein and fat) and herbage yield of graminaceous forage species (Bajwa et al., 1983; EL-Kassaby, 1985; Wani et al., 1991).

Forage yield and quality in relation to nitrogen nutrition: Dinanath grass is highly responsive to nitrogenous fertilizer (Bose, 1965; Mukherjee et al., 1976; Rathore and Kumar, 1977; Pal et al., 1975). Application of 49 kg N through FYM and 45 kg/ha through fertilizer produced 92 q/ha dry matter in single cut of
Dinanath grass. Top dressing of nitrogen at 4 weeks growth stage gives good results. In pure stand, 80 to 100 kg N/ha in two splits (half basal + half top dressed after 6 to 8 weeks of growth) may be applied. Application of 40 kg N/ha after every cutting is conducive for regrowth. At Hisssar increasing levels of N up to 120 kg/ha and phosphorus up to 60 kg P$_2$O$_5$/ha increased both green as well as dry forage yields (Narwal et al., 1977).

Mukherjee et al. (1976) reported that nitrogen up to 150 kg/ha increased the dry matter yield (133 q/ha) significantly. The optimum dose of nitrogen for Dinanath grass was found to be 145 kg N/ha. The cost:benefit ratio of fertilizer application was 10.2 and 9.5 at 100 and 150 kg N/ha, respectively.

In some of the studies conducted at Indian Grassland and Fodder Research Institute, Jhansi, Dinanath grass has been found to respond up to 120 Kg N/ha in pure stand (Mehlhl Lal and Tripathi, 1987 a). Abraham et al. (1980) concluded that application of nitrogen to Dinanath grass was beneficial for increasing yield and quality. They also reported that highest level of nitrogen (150 kg/ha) produced significantly higher forage yield than lower level of N (50 kg/ha).

Pandey and Dwivedi (1992) concluded that the plant height in Dinanath grass increased with increasing levels of nitrogen up to 120 kg/ha. The increase in plant height due to nitrogen application was also reported by (Cheema et al., 1975). The number of tillers were 39.2/hill at 90 kg N/ha and 40.7/hill at 120 kg N/ha. The number of leaves/plant as well as leaf length
increased due to application of nitrogen over control treatment both in single cut and double cut systems. Application of 90 and 120 kg N/ha produced leaves of 103.2 and 100.7 cm length. The green and dry forage yields of Dinanath grass significantly increased due to increase in nitrogen level up to 90 kg/ha. This has also been supported by Rathore and Kumar (1978).

A linear increase in green forage yield of 2.8, 2.2, and 0.6 q/ha was observed with each kg of nitrogen applied to Dinanath grass PP-10, PP-3 and sorghum JS-20, respectively. A linear increase in green and dry forage yield was obtained consistently with the application of 80 and 160 kg N/ha over control treatment (Tiwari, 1965; Sinha and Chatterjee, 1966; Narwal, 1970).

The studies conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1975-76, 1981-82, 1985-86, 1986-87, 1991-92) on the performance of *Pennisetum pedicellatum* in relation to nitrogen and phosphorus requirements revealed significant effect up to 150 kg N/ha at Kanke and Anand in terms of green forage yield in 1975-76. However, at Hyderabad significant increase was observed only up to 100 kg N/ha. In dry matter production, the significant response was obtained up to 150 kg N/ha at Kanke and up to 200 kg N/ha at Anand. In 1981-82, Dinanath grass produced significantly higher green forage yield (274.1 q/ha) at 100 kg N/ha which was at par with 150 kg N/ha (294.1 q/ha). However, significantly highest dry matter yield (99.3 q/ha) occurred at 150 kg N/ha. In 1985-86, significantly highest green and dry forage yields were observed
at 100 kg N/ha as compared to control treatments, however, the variation between the control plots and 50 kg N applied plots was not significant. In 1986-87 also, a linear increase in green and dry matter yield was observed due to increase in nitrogen from 0-100 kg N/ha. The experiment conducted at Palampur, Bhubaneshwar and Kanke in 1991-92 brought out that both green and dry forage yields differed significantly due to varying nitrogen levels from 0-90 kg/ha.

Nitrogen application increases crude protein and metabolizable energy but narrows down the nutritive ratio of forage (Menhi Lal and Tripathi, 1987 a). Studies conducted at Indian Grassland and Fodder Research Institute, Jhansi revealed higher forage as well as crude protein yield of range grasses due to the application of nitrogen ranging from 30-90 kg N/ha (Rai and Kanodia, 1981; Kumar et al., 1979; Kumar et al., 1980; Dwivedi et al., 1980).

Kumar et al. (1980) reported linear response to nitrogen up to 90 kg/ha, resulting in 135 % increase in dry matter and 153 % increase in crude protein yield of *Cenchrus setigerus* over control treatment.

Bhati and Singh (1982) summarised that the dry matter and crude protein yields increased significantly with the application of N up to 60 kg/ha. Forage yield attributes, viz., plant height and number of tillers as well as uptake of N and P increased significantly with the same nitrogen dose.
Rai and Kanodia (1981) found significant increase in crude protein yield (540.7 kg/ha) with nitrogen application of 120 kg/ha. The investigation on the effect of N on dry matter yield and quality of *Cenchrus ciliaris* x *Cenchrus setigerus* hybrid grown in pure and mixed with *Stylosanthes hamata* under rainfed condition at Jhansi (Rai, 1991) revealed that the highest dry matter (10.99 t/ha) and crude protein (1.16 t/ha) yields were obtained with 60 kg N/ha in pure stand which were significantly higher than the yields obtained with mixed stand receiving up to 30 kg N/ha. However, the crude protein content of grass was higher in mixed stand at all the levels of N than pure stand. On an average crude protein content of grass was higher (8.4 %) in mixed stand than pure stand.

**Nitrogen Economy Through Grass + Legume Intercropping:**

In fixing atmospheric N₂, legumes contribute to the N content of soil either as sole crops in rotation or as intercrops (LaRue and Patterson, 1981). In such systems, legumes may either increase the soil N status through fixation and excretion or in the absence of an effective N₂-fixing system, compete for N (Trenbath, 1976).

The quantity of N₂ fixed by the legume component in cereal legume intercropping depends on the species, morphology, density of legume in the mixture, the type of management, and the competitive abilities of component crops.
The literature on nitrogen transfer suggests that N₂ fixed by the intercrop legume may be available to the associated cereal in current growing season (Agboola and Fayemi, 1972; Remison, 1978; Eaglesham et al., 1981; Pandey and Pendleton, 1986) or as a residual N for the benefit of a succeeding cereal crop (Nair et al., 1979; Searle et al., 1981; Singh, 1983). Both forms of N transfer are considered to be important and could improve the N economy of various legume based intercrop systems.

Roots and nodules of legumes are thought to be the important sources of N transfer because of their high N contents (Butler and Bathurst, 1956). In cowpea, Minchin et al. (1978) found N from these sources only 6% of the total plant N, this may be inadequate to produce any substantial N benefit for a subsequent crop. From pot studies, Peoples et al. (1983) reported that N from roots and nodules of cowpea were 13% of the total plant N.

The degree to which N from intercropping legume may benefit a cereal crop depends on the quantity and concentration of the legume N, microbial degradation (mineralization) of the legume residues, utilization of these residues, and the amount of N₂ fixed by the legumes (Henzell and Vallis, 1977; Herridge, 1982). The rate of mineralization of organic N, determined by microbial activity, is primarily influenced by the prevailing moisture and temperature regimes (Ladd and Amato, 1984).

Ofori and Stern (1987) evaluated the N economy of maize-cowpea intercropping system using both N natural abundance and N labelled fertilizer methods. They found that cowpea maintained
its ability to fix atmospheric $N_2$ when intercropped with maize, but that $N_2$ fixation was reduced by $N$ fertilizer application. The comparable $P$ values (percentage of $N$ derived from atmospheric $N_2$) of the intercrop cowpea with or without applied $N$ was attributed to greater $N$ uptake by the associated maize, which induced the companion cowpea to be more symbiotic.

Rai et al. (1980) obtained maximum forage production with the introduction of phasbybean (Macroptelium lathyroides) followed by field bean (Lablab purpureus) with nitrogen equivalence of 129.9 and 121.1%, respectively. This in turn, indicated that with the introduction of these two legumes in Sehima-Heteropogon grassland, the dry matter yield can be increased equivalent to that obtained with 40 kg $N$/ha. Similarly, Rai (1985) reported that the intercropping of legume in buffel grass increased the total forage yield which was equivalent to the application of 60 kg $N$/ha.

The studies at Indian Grassland and Fodder Research Institute, Jhansi revealed that intercropping of Dinanath grass with cowpea and clusterbean fertilized with 55 kg $N + 45$ kg $P_2O_5$ per hectare produced herbage yield equivalent to pure grass receiving $90$ kg $N + 30$ kg $P_2O_5$ per hectare but gave 1.5 times more outturn of crude protein per unit area indicating that intercropping supplemented 35 kg $N$ with an additional application of only 15 kg $P_2O_5$ per hectare (Menhi Lal and Tripathi, 1987a).

There are three main sources of nitrogen in cereal-legume intercrop systems. These are, $N$ fixed by the legume component
from the atmosphere, from fertilizer, and from soil. The data published by Eaglesham et al. (1981) in Western Nigeria and Ofori and Stern (1987) in Western Australia offer some scope for illustrating N budgeting studies with maize and cowpea. Using equation suggested by Rennie et al. (1982) to calculate N from fixation, from fertilizer, and from soil, a N balance sheet was constructed for such a system with the data of Eaglesham et al. (1981). The densities of component crops, as sole crops were 60,000 plants/ha of maize, 1,10,000 plants/ha cowpea, the intercrop density was half of each sole crop density.

The N contributed by seeds of maize and cowpea at sowing was less than 2 kg/ha, fixed N$_2$ by intercrop cowpea was about 41 kg/ha and N from fertilizer was 3 kg/ha. The total N in the crops was about 99 kg/ha, consisting of N from seeds, fertilizer, N$_2$ fixation, and 53 kg/ha from the soil. Assuming a seed N harvest index of 36% for cowpea and 90% for maize, the quantity of N removed in the intercrop system was about 52 kg/ha, 28 kg/ha from maize and 24 kg/ha from cowpea. The N remaining in residues was 46 kg/ha.

The observations that the efficiency of cereal-legume intercropping relative to growing crops separately is greatest at low level of N, suggest that at low N, the intercrop legume has a greater dependence on atmospheric N$_2$ and presumably, competition from the associated cereal is minimised.

The production efficiency of cereal-legume intercropping could be enhanced through the use of more effective strains of
Rhzobia and low rates of fertilizer N so as to maximize N$_2$ fixation of the intercrop legume. This will partially eliminate competition for N between cereals and legumes as intercrops. To meet the high N requirements of the intercrop cereal while at the same time promoting N$_2$ fixation of the companion legume, slow release fertilizers might be used. This renders the N available to the cereal at about the peak vegetative stage, presumably after the N$_2$-fixing system of the legume has become well established.