DISCUSSION
Growth and Forage Yield of Component Crops in Relation to Weather Conditions:

The forage production per unit area per unit time is a resultant of the interaction between genotypes and environment. The environmental factors influence the structural (morphological) and functional (physiological) responses of plants in a coordinated manner to determine the level of crop yield. In the present investigation the average total (grass+legume) green forage (455.2 q/ha) and dry matter (87.4 q/ha) yields (Table 17 and Fig. 12 and 13) were higher in 1990 as compared to 1989 (334.8 q green and 73.3 q dry matter/ha). The pooled analysis of the data brought out significant variation in forage yield due to years indicating that the weather conditions exhibited a strong bearing on the growth performance and forage production of component crops. This was also reflected in considerable variation in herbage productivity as the green productivity was 5.4 q/ha/day in 1990 against 4.2 q/ha/day in 1989. This was attributed to favourable weather conditions in 1990.

The total rainfall during the crop season was higher in 1990 (844.1 mm) as compared to 1989 (487.5 mm). The total rainfall for crop period was received in 31 rainy days in 1990 against 15 rainy days in 1989 indicating that the number of rainy days was more than double in 1990.
Thus, the uniform distribution of rainfall accompanied with higher humidity in 1990 influenced the crop growth favourably (Chatterjee, 1973). Contrary to this, the year 1989 experienced critical dry spells, beginning from standard week No. 30 for a period of two weeks immediately after sowing which adversely affected the germination and establishment of component crops. Again the second long dry spell occurred from standard week No. 36 from 3rd September till the harvest of crops. This coincided with active grand growth period of crops resulting in low herbage yield. The maximum and minimum temperatures as well as evaporation beyond standard week No. 35 also remained higher in 1989 as compared to 1990. All these caused soil moisture stress coinciding with establishment stage and grand growth period in 1989 which adversely affected the number of functional leaves, length and breadth of leaf, leaf area index, leaf:stem ratio and relative leaf turgidity of the grass component. In turn, all these reflected in lower herbage yield per unit area per unit time in 1989 as compared to 1990.

Growth and Forage Productivity of *Pennisetum pedicellatum* Varieties:

The variation in green forage production of *Pennisetum pedicellatum* varieties was not significant in both the years. However, on the basis of pooled data, Bundel-1 outyielded both Bundel-2 and IGFRI-3808 in green forage production. On the other hand, Bundel-2 accumulated significantly higher dry matter as compared to Bundel-1 and IGFRI-3808 which in turn did not differ
significantly between themselves. Since, variety Bundel-1 maintained higher relative leaf turgidity than others at harvest, it resulted in greater green forage yield and productivity per unit area. Variety Bundel-1 contributed 56.4% to the total green forage yield against 63% by Bundel-2 and IGFRI-3808. The contribution of counterpart legumes was 43.6% in case of Bundel-1 and about 37% with Bundel-2 and IGFRI-3808. These observations indicate that Bundel-1 exhibited better association with companion legume than Bundel-2 and IGFRI-3808. Moreover, the legumes intercropped with Bundel-1 also exhibited greater number of plants per running metre, increased number of functional leaves per plant and higher dry matter accumulation. All these favoured high total (grass+legume) forage yield with Bundel-1.

Significantly greater dry matter accumulation with variety Bundel-2 is due to proportionately higher contribution from grass (68.5%) than from legume (31.5%) and higher contribution of grass is on account of greater number of leaves per shoot and comparatively higher leaf area index attributing to greater photosynthesizing surfaces and thereby, higher dry matter accumulation (Brown and Blaser, 1968). These findings corroborate with those obtained under All India Coordinated Research Project on Forage Crops (AICRPFC, 1984-85). All these ultimately lead to higher productivity per day in terms of green and dry matter yield (Table 18 and Fig. 14 and 15).
Effect of Nitrogen Nutrition on Growth and Forage Yield:

The increasing doses of nitrogen from 30 to 90 kg/ha significantly increased the green and dry matter production in both the years as also on the basis of pooled data with the result that highest forage yield was obtained at 90 kg N/ha (Table 17 and Fig. 12 and 13). The positive effect of nitrogen nutrition in enhancing the green and dry matter yield is associated with an increase in growth attributes such as number of tillers, plant height, number of functional leaves of grass component as well as leaf area index and dry matter content (Table 3, 4, 8, 9 and 10 and Fig. 3, 4, 5, 6 and 7). This is because of the fact that nitrogen is involved in increasing protoplasmic constituents and accelerating the process of cell division and elongation which in turn give luxuriant vegetative growth for higher forage productivity (Watson, 1952).

Tregubenke and Filippov (1968) found an increase in the amount of most strongly bound water and water potential of leaf cells by increasing the nitrogen-phosphorus nutrition. Nitrogen nutrition induces an enhancement in the water retaining forces of the cell and reduces the rate of transpiration in the leaves and ultimately stimulates growth, resulting in better crop yield. Singh (1980) also reported that nitrogen nutrition enhances the growth and yield of maize by stimulating various metabolic processes. Nitrogen is the key element in grass growth and is the most limiting nutrient in the Indian soils. Its application not
only increases the green and dry matter yields but also influences the quality (Menhi Lal and Tripathi, 1987a) of forage, particularly the level of protein. The favourable effects of nitrogen on growth attributes (plant height and number of leaves), quality parameters (protein and fat) and herbage yield of sorghum have been reported by Bajwa et al. (1983), EL-Kassaby (1985) and Wani et al. (1991).

Effect of Pure and Mixed Stands of *Pennisetum pedicellatum* on Growth and Forage Yield:

Pure stand of *Pennisetum pedicellatum* significantly out-yielded Dinanath grass + cowpea and Dinanath grass + clusterbean in green as well as dry matter production in both the years. Comparatively lower yield in intercropping system may be attributed to 50 % replacement (2:2 row ratio) of grass by legumes having relatively less production potential. This is however, compensated by improvement in forage quality particularly in terms of crude protein content of both the component crops and its total outturn in the sward. However, both the intercropping systems differed significantly between themselves in dry matter accumulation but not in green forage production. Significantly highest green and dry matter yield in pure stand is attributed to more number of shoots per running metre and higher leaf:stem ratio. Dinanath grass + clusterbean showed an edge over Dinanath grass + cowpea in green forage and dry matter yield. Such differences in the productivity are
associated with better plant height, LAI, RWC, root mass of grass in association with clusterbean than cowpea. Moreover, higher dry matter content of clusterbean also contributed to higher dry matter production of this combination.

The contribution of grass to total herbage production was 66.0% with clusterbean against 55-60% with cowpea. The better associative effect of clusterbean with grass in comparison to cowpea is primarily due to erect nature of growth of clusterbean which lends favourable environment for grass growth in mixed stand. Tripathi et al. (1984) also observed higher dry matter yield with Dinanath grass + clusterbean than Dinanath grass + cowpea.

Effect of Treatment Variables on Quality Traits:

Crude protein: All nitrogenous substances contained in feed stuff which include the true proteins (composed of a number of amino-acids) and non-protein nitrogen (NPN) compounds, are collectively called crude protein. *Pennisetum pedicellatum* variety Bundel-1 showed significantly higher crude protein content in both the years (Table 20 and Fig. 16) and crude protein yield in 1989 (Table 22 and Fig. 17). The higher crude protein content and yield of Bundel-1 at low and medium level of nitrogen is due to its longer leaf area duration and greater relative leaf turgidity maintained in this variety at harvesting stage. Moreover, the associated legumes by virtue of its higher number of leaves as well as greater degree of nodulation supplemented considerably in
improving the crude protein content in this variety. The favourable effect of associated legume on quality traits of grass may be attributed to nitrogen fixed by the intercrop legume and its transfer to the associated cereal component (Agboola and Fayemi, 1972; Remison, 1978; Eaglesham et al., 1981; Pandey and Pendleton, 1986). Moreover, roots and nodules have been regarded as important sources of N transfer because of their high N contents on one hand (Butler and Bathurst, 1956) and nitrogen supplying power to associated cereal crops on the other (Henzell and Vallis, 1977; Herridge, 1982).

The intercropping of Dinanath grass with forage legume caused an increase in crude protein content of grass component. On an average Dinanath grass intercropped with cowpea contained 7.2 % crude protein against 6.9 % when intercropped with clusterbean and 6.3 % in pure grass stand. The total outturn of crude protein was also higher with Dinanath grass variety Bundel-1 + cowpea combination in 1989 than Dinanath grass + clusterbean. This kind of variation in crude protein yield is an outcome of proportionately greater contribution of cowpea containing higher level of crude protein (Menhi Lal and Tripathi, 1987 b). Moreover, 3.5 times greater number of nodules higher leaf:stem ratio and leaf turgidity of cowpea in comparison to clusterbean lead to greater contribution to crude protein yield. In 1990, Dinanath grass + clusterbean showed marginally an edge over Dinanath grass + cowpea in crude protein yield due to relatively higher green and dry forage yield.
Nitrogen nutrition influenced the level of crude protein favourably up to 60 kg N/ha in 1989 and up to 90 kg N/ha in 1990. The increase in crude protein content with increasing levels of fertilizer nitrogen is an expression of the part played by nitrogen in protein synthesis (Abraham et al., 1980). Increase in crude protein content of Dinanath grass following nitrogen application was also reported by Narwal et al. (1977). Considerable evidences are available to show the key role of fertilizer nitrogen in increasing crude protein content and forage quality (Oberoi, 1980: Mannikar, 1980).

Water soluble carbohydrates (WSC): Glucose, fructose, sucrose and fructans are the main WSC in grass. Oligosaccharides other than sucrose have been detected but it is doubtful if these are present in significant quantity (Butler and Bailey, 1973). Soluble carbohydrates are important in helping to prevent hypomagnesemia and perhaps hypocalcemia. Metson et al. (1976) believed that the protective role of readily available carbohydrates may be partly due to their role in providing essential energy and carbon requirements for fatty acid and protein synthesis.

There was significant variation in WSC contents of Pennisetum pedicellatum varieties in both the years. Variety IGFRI-3808 contained highest WSC content (5.1 %) in 1989, whereas, in 1990, variety Bundel-1 exhibited highest WSC content of 3.9 per cent. The higher WSC content in variety IGFRI-3808 is
associated with its high photosynthetic rate as a function of more number of tillers, taller plant height and greater leaf area index. Forage legumes intercropped with *Pennisetum pedicellatum* variety IGFRI-3808 consistently exhibited higher WSC content on account of higher relative leaf turgidity resulting into longer period of carbohydrate synthesis with this combination.

*Pennisetum pedicellatum* and cowpea when grown in association accumulated significantly higher WSC than the pure grass stand in both the years. The higher WSC content with this combination is a resultant of their photosynthesizing characters viz., greater number of leaves and leaf:stem ratio in grass component and taller plant height, greater number of leaves, more leaf:stem ratio and increased leaf turgidity in legume component. In 1990, in intercropping, *Pennisetum pedicellatum* with cowpea gave highest WSC content at 30 kg N/ha whereas, with clusterbean WSC content was highest at 90 kg N/ha (Table 25). This could be substantiated by the fact that cowpea with better nodulation and nitrogen fixing characteristics caused associated grass to maintain higher level of WSC content at low (30 kg/ha) nitrogen dose. On the contrary, the grass associated with clusterbean, possessing comparatively less nodulation and nitrogen supplying power, demanded high nitrogen (90 kg/ha) to give maximum WSC content.

In general, increasing levels of fertilizer nitrogen from 30 to 90 kg/ha increased the content of WSC in Dinanath grass but decreased in forage legumes. Variety Bundel-1 consistently gave
higher WSC content at 90 kg N/ha. The increase in WSC of grass is linked with metabolic role of nitrogen in photosynthetic process (Singh, 1980). On the other hand, decrease in WSC content of legume is due to simultaneous increase in crude protein content which is inversely related to carbohydrates content (Thakre, 1987).

Oxalate content: Oxalic acid is one of the toxic substances occurring naturally in *Pennisetum* and *Setaria* species. These anti-quality substances cause direct metabolic damage to the animal or interfere with some phase of digestive utilization (Butler and Bailey, 1973). Excess of oxalate in feeds and fodders depletes body calcium of animal in the form of calcium oxalate, develops renal malfunctions and various other syndromes in ruminants.

*Pennisetum pedicellatum* variety Bundel-2 consistently gave lowest oxalate content even at 30 kg N/ha. On the other hand, variety Bundel-1 exhibited highest oxalate content in both the years. Variety IGFRI-3808 occupying intermediate position in this respect showed declining trend in oxalate content with each additional dose of fertilizer nitrogen. In general, increasing doses of nitrogen from 30 to 90 kg/ha decreased the oxalate content.

The association of forage legume in reducing the oxalate content of Dinanath grass was observed in relatively dry year (1989) but not in wet year (1990) and more so, the effect was
pronounced in association with cowpea. Intercropping high yielding grass species with suitable forage legumes has been reported to reduce anti-quality factors like oxalates in hybrid napier, besides providing balanced and nutritious herbage to animals (Tiwana and Bains, 1976; Patel et al., 1973).

Fibre fractions: Crude fibre represents the frame work of the plants and includes cellulose, hemicellulose and lignin fractions of the cell wall. Neutral detergent fibre (NDF) is an estimate of cell wall content and acid detergent fibre (ADF) is actually a measure of lignocellulose complex in the forage materials. *Pennisetum pedicellatum* variety Bundel-1 contained lowest percentage of most of the fibre fractions (NDF, ADF, cellulose and lignin) indicating that this particular variety does not become too fibrous even at flowering stage (Table 28, 29, 32 and 33 and Fig. 20, 21, 23 and 24). In other words, it maintains the desirable quality characteristics of higher intake and digestibility. Legumes in association with variety Bundel-1 indicated highest NDF, ADF and hemicellulose and lowest lignin and acid insoluble ash content. Forage legume in association with Bundel-2 indicated highest content of cellulose and lignin and minimum content of NDF and hemicellulose. Lowest ADF and cellulose content was observed in legumes intercropped with Dinanath grass variety IGFRI-3808 with highest content of lignin.
Dinanath grass grown as pure stand exhibited highest contents of NDF, ADF, cellulose, hemicellulose and acid insoluble ash. Intercropping clusterbean with *Pennisetum pedicellatum* reduced the contents of NDF, ADF and cellulose. On the other hand, cowpea intercropping caused a decrease in hemicellulose and acid insoluble ash in grass component.

Nitrogen nutrition had no significant and consistent effect on fibre fractions of *Pennisetum pedicellatum*. However, low NDF and hemicellulose content was observed at 90 kg N/ha whereas, minimum content of ADF and cellulose was observed at low to medium level of fertilizer nitrogen. In so far as the effect of nitrogen nutrition on fibre fractions of legume component was concerned, application of 30 kg N/ha resulted in lowest content of NDF, ADF, hemicellulose and cellulose. Nitrogen nutrition exhibited favourable effect in reducing lignin content of legumes in wet year but not in dry year.

**Nitrogen Uptake in Relation to Treatment Variables:**

On an average *Pennisetum pedicellatum* variety Bundel-1 caused higher uptake of nitrogen in both the years. This was followed by Bundel-2 in 1989 and by IGFRI-3808 in 1990. The higher uptake of N by Bundel-1 is associated with its higher nitrogen content and greater proportion of nitrogen rich legume as compared to other varieties.

Nitrogen uptake remained higher in intercropping system as compared to pure stand of grass in both the years. Among
intercrops, the association of cowpea exhibited greater N uptake by sward than association of clusterbean. The change in the pattern of nitrogen uptake by grass varieties Bundel-2 and IGFRI-3808 and also by the intercropping systems over the years was an interplay of proportionate contribution of legume component to the total herbage yield (Henzell and Vallis, 1977; Herridge, 1982).

Increasing levels of nitrogen from 30 to 90 kg N/ha caused an increase in the uptake of nitrogen in both the years but the differences were significant only in 1990 when the magnitude of increase was of higher order. This was because of the fact that additional doses of nitrogen showed two fold benefits of increasing dry matter yield and improving the nitrogen content of grass component simultaneously. The advantages of nitrogen nutrition in enhancing the yield and quality of cereals have been reported by many workers (Oberoi, 1980; Mannikar, 1980; Menhi Lal and Tripathi, 1987 a; Tripathi and Singh, 1991).

Response to Fertilizer Nitrogen:

The response to applied nitrogen is a function of varietal characteristics and their associability with forage legumes in intercropping systems. The data on nitrogen response in relation to *Pennisetum pedicellatum* varieties and crop stands (Table 38 to 41) and (Fig. 27 and 28) indicated linear response to applied nitrogen for all the varieties. This therefore, suggests that within the range of 30 to 90 kg N/ha, the *Pennisetum pedicellatum*
varieties with differential growth rhythm responded linearly to nitrogen fertilization under rainfed environment. In view of linear nature of response functions, it was not possible to work out the optimum dose of fertilizer nitrogen. A linear increase in green and dry forage yields was also obtained with application of every additional dose of nitrogen over control treatment by Tiwari (1965), Sinha and Chatterjee (1966) and Narwal (1970). The studies conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1975-76) also revealed significant effect of nitrogen nutrition on green forage yield of Dinanath grass up to 150 kg/ha at Kanke and Anand. However, in case of dry matter production the significant response occurred up to 150 kg N/ha at Kanke and up to 200 kg N/ha at Anand. At IGFRI Jhansi, higher green forage as well as crude protein yields of grasses have been obtained with application of nitrogen ranging from 30 to 90 kg/ha (Rai and Kanodia, 1981; Kumar et al., 1979; Kumar et al., 1980: Dwivedi et al., 1980).

The response to per kg of applied nitrogen varied from variety to variety and the degree of response decreased with increasing doses of nitrogen in all the varieties. Dinanath grass variety Bundel-2 registered the highest degree of response to each kg of fertilizer nitrogen specially in terms of dry matter production.

Production functions showed linear response of fertilizer nitrogen in relation to crop stands. However, the magnitude of response to each kg of applied nitrogen at all nitrogen levels
was higher in pure Dinanath grass than its association with cowpea or clusterbean. This suggests that association of legumes supplemented to the nitrogen requirements of associated grass species, thereby, showed lower degree of response in intercropping systems. Rai (1991) also revealed that the highest dry matter and crude protein 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.

In intercropping system *Pennisetum pedicellatum* variety Bundel-1 exhibited highest response to per kg applied nitrogen in green forage production whereas, in dry matter production variety Bundel-2 excelled others.