DISCUSSION

The recognition that adequate improvement in milk production can be achieved more by increasing the availability of fodder and feed to the cattle than by genetic upgrading alone, is gaining momentum in recent years. It has also been found that the cheapest way of providing better nutrition is through cultivation of high yielding and nutritive fodder crops like berseem, lucerne etc., as these can sustain about 10 litres of milk production in addition to the per day maintenance requirements of animals (Ray, 1967; Stone, 1972).

The livestock population has continued to increase from 296 million in 1951 to 336 million in 1961 and 365 million in 1971, thus increasing the pressure on our land for its fodder and feed resources. Hardly 4.5 per cent of the cultivated area is under fodder crops which can meet only a small fraction of the fodder requirements of the livestock population. This gap between the cultivated area and the fodder requirements, has, however, continued to widen. The scope for increasing the land under cultivation being limited, the productivity per hectare has to be increased by better utilization of the resources like land, irrigation, fertilizers and manures, by growing more than one crop in a year to increase the yield per unit land per unit time. So far, the increase in crop output has been low due to low yield of individual crops and inefficient cropping pattern. The evolution and introduction of high yielding varieties and hybrids of crop plants and matching advances made in agronomy and plant protection have paved the way for stabilized and increased agricultural production. There are many possible
combinations of forage as well as feed crops that may yield better in quantity and quality and could thereby help to provide enough nutrients to support the required number of cattle. The present study was hence taken up to evaluate twenty, one-year feed and fodder crop sequences of different cropping intensities for their economic production potential, nutritive value, carrying capacity per hectare and their economics as crop and dairy enterprises. Their effects on the fertility status of the soil were also investigated.

The salient features of the results based on statistical analysis of data on fresh yield, dry-matter yield, nutritive value, economics and employment potentials and effects on physical and chemical properties of soil are discussed below.

**Fresh Yield:**

The mean yield of k-crop sequences (1832 q/ha) was found to be significantly higher than the mean yield of rotations with three fodder crops and intercropping of hybrid napier with legume fodder. The treatment T-19, consisting of bajra (kharif), turnip (zaid), oats (rabi) and maize+ cowpea (summer) gave the highest yield of 2208 q/ha of green fodder amongst the fodder-based cropping patterns. Treatment T-18, which differed from T-19 only in respect of the kharif crops, (maize+cowpea in the former and bajra in the latter), followed T-19 closely with an yield potential of 2207 q/ha.

On examining the contribution made by individual crops to the total fresh yield of the sequence, it was found that T-19 occupied the most superior position mainly on account of the high yielding forage crop, bajra.
During the kharif season, bajra (with two cuts) under T-19 recorded an yield of 707 q/ha which was not only the highest but also was about 275 q/ha more than the fresh yield obtained with maize+cowpea under T-18. As a rabi fodder, oats either under T-18 or T-19, yielded only 587 q/ha as against the best rabi fodder, berseem which recorded as high an yield as 935 q/ha under the treatment T-11. Similarly in the summer season, maize+cowpea under T-18 or T-19 recorded yields of the same order (448 and 432 q/ha) but was definitely inferior to the best summer fodder yield of 756 q/ha obtained with bajra under T-13. In zaid season, turnip under T-18 yielded 739 q/ha which was about 57 q/ha more than the yield of turnips recorded under T-19. The results, therefore, clearly provide indications that bajra which has a regenerating ability to provide fresh and succulent fodder within a short period of 90-92 days, as a result of which it becomes useful in maintaining green supply to cattle, was responsible in pushing the yield of T-19 to the top position.

In the 3-crop sequence group, T-13 (sorghum - berseem - bajra) and T-11 (maize+cowpea - berseem - bajra) gave yields of the same order (about 2030 q/ha) and were definitely superior than any other treatment in the group. These have emerged as the best treatments of the group mainly on account of bajra (744 q/ha) raised in summer season which produced about 300 q/ha more than the summer fodder in other sequences of the group except T-17 which also involved bajra fodder and yielded 637 q/ha. The differences in the yields of rabi and kharif fodders were not very substantial.

Intercropping of hybrid napier with berseem during the rabi season in T-10 produced 204.0 q/ha green fodder in one year which could favourably
be compared with the yields of berseem based 3-crop rotation T-13 and T-1d. Berseem yielded 635 q/ha as an intercrop in this treatment which was about 300 q/ha less than the highest yield of pure crop obtained in T-11 consisting of maize+cowpea - berseem - maize. The reason for such a low yield of berseem in intercropping with hybrid napier was given by Singh (1972). He reported that in plots where berseem was sown as an intercrop, the field preparation could not be very good and this resulted in producing lesser quantity (50 per cent) of green fodder. Several workers have reported that pure stand of legumes with optimum plant density resulted in better growth and higher green yields than the mixed or intercropped stands (Clements et al., 1929; Davies et al., 1953; Costa and Chandler, 1956; Fribourg and Bartholomew, 1956; Hadric and Richardo, 1957; Boucrarolli, 1966; and Kynewer, 1966). The total yield obtained from intercropping in this treatment was, however, better than the ones reported by Singh et al. (1969), Hukkeri (1971) and Paroda et al. (1972) but was of the same order as that of Singh (1972). The mean yield of hybrid napier obtained from T-7 (1580 q/ha) when it was intercropped with pea (G) was, however, found significantly higher than that of T-10 (1140 q/ha). This significant difference of more than 150 q/ha in yield from T-7 could be attributed to the low frequency of irrigation to the companion crop of pea due to which loss of clumps by rotting is reduced and trailing-cum-spreading nature of peas that might help in covering the hybrid napier clumps and result in saving the ratoon from the effects of low temperature of winter.

The grain yield potential of feed crops, maize and oats, used in different cropping patterns during kharif and rabi ranged from 58 to 60 q/ha
and 32 to 34 q/ha, respectively. They exhibited no significant differences in their grain yields among the treatments, thereby indicating that these were not influenced by various crop combinations. However, in the case of oats, 40 q/ha of straw was obtained more from 2-crop sequence, T-3 (159 q/ha) comprising of sorghum fodder followed by oats for grain, than from a 3-crop combination, T-5 (122 q/ha) involving sorghum (F) fodder, oats (G) and maize-cowpea (F). The treatment T-8 comprising of all the feed crops maize - oats - mung produced the highest yield of about 165 q/ha of oats straw which was of the same order as that of T-3.

**Dry-matter yield:**

The presence of moisture in plant varies with the stage of maturity, time of last irrigation before harvest and several other factors. To avoid misleading results due to this reason in fresh components, it was considered essential to determine the dry-matter yield of the produce and the results based on them are discussed here.

The sequence involving feed (grain) crops only (T-8 consisting of maize - oats - mung) produced more dry-matter as compared to the sequences involving either fodder crops alone or combinations of fodder and feed crops. The average dry-matter produced under T-8 was of the order of 346 q/ha which was about 17 and 31 q/ha more than fodder-based rotations and feed and fodder rotations respectively. However, on examining the individual treatment sequences, T-13 consisting of sorghum - berseem - bajra and T-5 involving sorghum (F) - oats (G) - maize-cowpea (F) were found to be the most superior dry-matter producers with yields of the order of over 390 q/ha followed closely by T-19 with yield of 381 q/ha with
bajra - turnip - oats - maize+cowpea. The detailed study of the performance of the crops of T-13, T-5 and T-19 in different seasons revealed that T-19 which had also produced the highest green matter provided consistent supply of dry-matter through different seasons as against T-5 and T-13 which gave higher dry-matter in rabi and summer seasons respectively.

During kharif, sorghum (F) did not indicate significant difference in its dry-matter yield when grown in sequences like T-5 comprising sorghum (F) - oats (G) - maize+cowpea (F) (155 q/ha) and T-13 (sorghum - herseem - bajra) (156 q/ha). The dry-matter yield of bajra (kharif) in T-19 was, however, less by about 12 q/ha of sorghum fodder. Of the rabi crops, the oats cultivated either for grain or fodder were first harvested for fodder after about 78 days of sowing, 25 cm above the ground to get better regeneration of plants as recommended by Singh (1970). He reported that by cutting oats after two and a half month of sowing, it was not only advantageous to get fodder for feeding cattle but subsequently the grain yield also improved. The total dry-matter obtained from grain oats (with one cut of fodder) in a 3-grain crop sequence, T-3 (with preceding crop of maize) was the highest (198 q/ha). The yield was, however, less from the crop following sorghum (F) by 31 q/ha in T-5 and 17 q/ha in T-3 while in T-4, the difference was of the order of 10 q/ha only. It was also noted that the dry-matter yield from the first cut of fodder was significantly higher by 5 q/ha in fodder-based sequences than of feed and fodder crops. In the k-crop sequences oats was cultivated after zaid crop of turnip or mustard and as such only one cut of fodder was taken. On comparing the combined dry-matter yield of turnip and oats (156 q/ha) with the mean yield of oats giving 2 cuts of fodder (140 q/ha),
it was observed that the dry-matter from the latter was about 16 q/ha less. Another interesting observation about oats was that though its dry-matter yield from grain indicated no statistical difference in dry-matter yield from different cropping patterns, yet its yield from straw showed significant differences among the treatments. The feed crop combination (T-8) gave a significantly higher yield of about 23 q/ha over that of feed and fodder crop sequences and this high yield of dry-matter obtained from oats straw after maize (G) in T-8, may be the possible contributory factor to raise its total dry-matter production. The reason for the high yield of dry-matter from oats might be due to the residual effect of the preceding crop of maize.

Bajra, following berseem in a 3-crop fodder sequence T-13 (sorghum - berseem - bajra) with its potential of 153 q/ha outyielded all other crops grown in summer. Its combined yield with sorghum (kharif) or berseem (rabi) was also the maximum that could be observed among the treatments. Thus the presence of such combination of high yielding summer bajra with kharif sorghum and berseem (rabi) raised the treatment T-13 to the first position. Similarly the top rank among the 4-crop sequences was attained by T-19 (381 q/ha) where bajra (kharif) with its significantly high yield of 143 q/ha was in combination with 62 q/ha of turnip (zaid), 94 q/ha of oats (rabi) and 51 q/ha from maize+cowpea (summer).

The results thus lead to the conclusion that (a) the high out-turns from cropping patterns were based on the combined yields of different crops grown in different seasons, (b) oats straw yielded significantly higher from feed-based than the fodder and feed sequences, (the yields were higher when oats followed maize (G)) and (c) bajra showed significantly higher yields during kharif and summer.
Nutritive Value and the Number of Milch Animals that can be Supported Per Hectare:

The cropping patterns that produced both D.C.P. and T.O.N. in good amount as well as in right proportion could support the maximum number of milch animals on a hectare of land. The treatment T-13 comprising sorghum (kharif), berseem (rabi) and bajra (summer) was found to be the best combination of fodder crops producing 203.4 q/ha of green fodder with 395.7 q/ha dry-matter, 27.7 q/ha D.C.P. and 227.5 q/ha T.O.N. per year that could support 8.8 buffaloes with 450 kg body-weight, yielding 3,000 litres of milk with 7.0 per cent butter-fat and 10.9 buffaloes of 400 kg body-weight and yielding 2,000 litres of milk per annum with 7.5 per cent butter-fat. The corresponding figures for cows with the same yield and body-weights of 400 kg and 350 kg; and butter-fat 4.0 and 4.5 per cent were 11.1 and 13.6 respectively. This rotation ranked supreme due to the presence of high yielding and nutritious fodders of berseem and bajra. Berseem yielded on an average 868 q/ha of green fodder with 88.3, 15.1 and 55.8 q/ha of D.M., D.C.P. and T.O.N. respectively. Bajra too, produced good roughage with 756 q/ha of green fodder having 145.2 q/ha D.M., 10.5 q/ha D.C.P. and 90.1 q/ha T.O.N. per day.

Berseem, being a leguminous crop, was rich in D.C.P. and its substantial contribution in raising the productivity was evident from the fact that all the berseem-based cropping patterns (T-11, T-12, T-13 and T-14) showed promising results of carrying capacity. A valuable role played by berseem in feeding of dairy animals was reported by several workers (Mathur, 1963; Ray, 1967; Saran and Jackson, 1967; Daniel et al. 1967). Mudgal (1971) reported that the use of leguminous fodder not only
reduced greatly the amount of protein supplement required to balance the ration but also helped to increase the palatability of the total ration and digestion of more of crude fibre in straws increasing thereby the nutritive value of the coarse roughage instead of depressing it as in the case of high concentrate ration. Daniel et al. (1967) and Lal and Mudgal (1970) suggested that the protein supply for maintenance and production of milk up to 10 kg a day could be met from 50-55 kg of green berseem alone. Das Gupta (1963) could not find any effect on the health and milk yield of the cows when berseem replaced concentrates.

The presence of high yielding nutritious fodder of bajra (2 cuts) appeared to have raised the position of the cropping patterns in meeting the requirements of milch animals per hectare. Bajra (kharif) produced 1.3 kg D.C.P. and 4.1 kg T.D.N. per day more in T-19 when it replaced a kharif crop of maize and cowpea mixture (T-18). A 4-crop rotation (T-19) consisting of bajra, turnip, oats and a mixture of maize and cowpea ranked second in raising milch animals of different categories (C-I, 8.5; C-II, 10.9; C-III, 10.9 and C-IV, 13.9) followed by T-20 involving all the non-leguminous fodder crops. The major contributory factor of such a high carrying capacity was the high yields of bajra, turnip/mustard and oats which though non-leguminous, had produced large quantities of D.C.P. and T.D.N. in right proportions. Moreover, the superior position of T-19 over T-20 could be due to the inclusion of summer and zaid fodders of maize+cowpea and turnip having an average yield of 73.3 kg and 73.2 kg T.D.N. and 4.4 kg and 10.5 kg D.C.P. per day, respectively against a short duration non-leguminous and comparatively low yielding fodders of cheena and mustard with 66.5 kg and 41.4 kg T.D.N. and 4.19 and 6.73 kg D.C.P. per day per hectare respectively.
A productive and nutritious combination of berseem and bajra showed better results with a kharif crop of sorghum (T-13) than with a mixture of maize-cowpea (T-14) as the former with high contents of T.O.N. (92.1 kg) could balance the availability of D.C.P. and T.O.N., while the latter, though enriched the treatment (T-14) with the D.C.P. (7.9 kg), was unable to maintain the high number of animals due to comparatively low production of T.O.N. (55.5 kg).

On comparing treatment T-17 consisting of senji during rabi with the berseem based cropping patterns, it was observed that senji gave a little less but comparable output of digestible nutrients as well as carrying capacity. The crop, however, does not have the characteristics of supplying continuous green roughage at short intervals like a multi-cut crop of berseem, and as such could not be considered at par with berseem from a dairy husbandry point of view.

Oats with two cuts of green fodder, produced comparatively low amount of D.C.P. (7.56 kg per day) than berseem (8.5 kg per day) and hence the crop sequences comprising of this crop (T-15, T-16) could not match well. It was, however, worth-noting that, when the combined yield of D.C.P. and T.O.N. obtained from oats (sown in December) and the preceeding zaid crop of turnip or mustard was considered against berseem, the latter combination could be adopted with success as was evident from the results of T-19 and T-20. These cropping patterns yielded over 200 q/ha of green fodder per year and could be considered better than the ones reported by the N.D.R.I. (1971), Relwani (1970, 1971), Sundaresan (1970, 1971, 1972) since they could obtain only 150 to 160 t/ha of green fodder per year that could support about 10 cross-bred cows of 3 to 4 years of age yielding 2500 litres of milk per annum. These workers did not enumerate the amount of
nutrients obtained from each crop in various seasons but suggested to feed some concentrates during lean period to the cattle.

Swaminathan et al. (1970) reported the carrying capacity of some fodder rotations tried at the Indian Agricultural Research Institute during the year 1969-70 and these results were in agreement to their findings.

Hybrid napier grass which gave bumper yields when intercropped with leguminous crops like pea (T-7) and berseem (T-10) yielded a good amount of D.C.P. (6.7 and 8.7 kg per day) and T.D.N. (56.1 and 51.5 kg per day) and the number of animals in milk of different groups that could be maintained on such treatments varied from 7.9 to 12.2 and 7.3 to 11.2 per hectare. Higher contents of T.D.N. in T-7 (56.1 kg), which was due to grain crop of pea, raised its rank over T-10 which was intercropped with berseem and yielded proportionately more of D.C.P. but less T.D.N.

These results compared well with the other treatments consisting of annual crops of legumes and non-legumes. It would be worth-pointing that high amount of digestible nutrients from these treatments could be obtained only due to the timely cuttings of grass with an interval of 45 to 50 days when the crop attained a height of about 1.2 to 1.4 meters, as was recommended by Mudgal and Des Raj (1966) and supported by Ghosh (1970) and Singh (1971).

The perennial crop of lucerne in T-9 with carrying capacity of 4.9, 6.1, 6.2 and 7.6 milch cattle of C-I, C-II, C-III and C-IV respectively per hectare could find its place at eighteen due to its poor yield of T.D.N. (34.9 kg per day) though it yielded the highest amount of D.C.P. (9.3 kg per day) for 11.7, 15.0, 15.0 and 19.0 milch animals of corresponding groups. Being rich in D.C.P. contents, several workers pleaded its feeding
for providing economic and balanced ration to the cattle kept on green roughage alone. Yoelao (1968) found lucerne as good as berseem under ad libitum feeding for milk production in cows and buffaloes. A partial supplementation of lucerne for concentrate was shown to reduce feed costs with buffaloes at Anand also (Patel et al., 1969).

Out of the treatments comprising of feed (grain) and fodder crops, T-6 with maize (G) - oats (F) - maize+cowpea (P) indicated better results than all other crop combinations. A good amount of digestible nutrients from two cuts of oats fodder, maize grain and its succulent straw at the time of its harvest and from maize+cowpea mixture raised favourably the rank of the treatment for comparing with other treatments of grain and fodder crops as well as the treatment T-8 comprising all grain crops. The results of the present studies corroborate the earlier findings (Ray, 1967; Mudgal, 1967; Patel, 1970; E.S. A.I., 1971) that good quality forages were the primary requirement of the dairy industry and it would be advantageous to supply nutrients through good quality roughages as far as possible.

There is one lacuna in the observations made above which stands in the way of actual feeding practices. In the above accounts, the calculations have been made on the basis of total quantity of nutrients available per year per hectare. However, this does not take into consideration the seasonal variations i.e. when only one particular type of fodder is grown in a season for feeding the animal at that period. It may so happen, particularly with root crops like turnip, that the feed available will be comparatively poor in protein content for the maintenance of milk yield. The deficiency will either have to be
supplemented with concentrate feed, like oil cakes or simultaneously with silages or legume hays prepared out of highly nutritive crops like oats, maize or berseem and lucerne.

Effect on Chemical Properties of the Soil:

The soil fertility changes after the end of a rotation are of considerable importance since they determine the long-term effects of following any rotation on soil productivity as well as the long-term economics of the rotation chosen. The results of the present investigation provided some useful information in this regard.

None of the cropping patterns produced significant build-up of either organic carbon or available potash (K) which, on the other hand, tended to show a decrease at the end of the rotation although these rotations involved the use of N, P₂O₅ and K₂O as fertilizers. This is contrary to the findings of Blair and Prince (1936), Hoffmann et al. (1950) and Ghosh and Kanzaria (1964) who did not find any change in soil potassium as a result of cultivation including the use of potassic fertilizers. This indicated that the dose of K₂O fertilizers used in this investigation was insufficient on the basis of the current practices when these crops were combined in an intensive cropping system. This was clearly indicated by the rotations involving grain crops, the 1-crop fodder based rotations and those involving 300 per cent cropping intensity but including berseem in the sequence. This calls for a revision of the currently held impression that the soils of Delhi contained a good amount of potassium and berseem requires more phosphorus (P) than anything else especially when intensive rotations were planned.
The reverse seems to be true of phosphorus (P). Although three of the rotations viz. T-8, maize (G) - oats (G) - mung (J), T-12 (sorghum - berseem - maize+cowpea) and T-19 (bajra - turnip - oats - maize+cowpea) caused a depletion, most of other rotations were leaving a build-up of this nutrient in the soil. The exceptions consist of the feed-based sequence T-8, T-12 and 4-crop sequence, T-19 in which increase of phosphorus application was indicated by this study. It appears that the $P_2O_5$ dose could be lowered in the remaining cases from the point of view of maintenance of soil P making them more economical. Many other workers had also reported an increase in soil available phosphorus (Sandal and Pal, 1965; Ghosh and Kanzaria, 1964; Bucher, 1951 and Hedlin and Aidley, 1964) from which a similar inference could be drawn regarding the possibility of reduction of the $P_2O_5$ dose applied.

More fundamental than the changes in soil phosphorus and potassium are those associated with soil organic matter. The latter is known to influence soil productivity by its effect on soil physical and biotic condition, buffering capacity, chelating effects resulting in the greater availability of phosphorus and micronutrients and in reflecting the reserves of the soil nitrogen. Although legumes were reported to increase the soil organic matter content, the literature is by no means very conclusive. While the legumes were found to increase organic matter of soils by Jones (1942), Smith (1950), Moore (1962), Watson (1963) and Nixon (1966), some workers like Dubetz and Hill (1964) found that soil organic matter was maintained only in rotations containing 3-years of lucerne. Bear (1965) in fact pointed out that organic matter could be built up only by using a small excess of nitrogen along with a legume programme.
This seems to suggest in this study that this condition was not fulfilled since there was no build-up of the soil organic matter.

Treatment 1-9 containing only lucerne was found to be the best of all rotations from the point of view of the least depletion of soil organic matter. This was in keeping with the extensive root reserve which this crop would leave in the soil as reported by Aliere (1961) and Davies (1964).

All the grain and fodder crop sequences (T-1, T-2, T-3, T-4, T-5 and T-6) except perennial grass intercropped with a grain crop of pea (T-7) and all fodder-based rotations including bajra or those having less than half the number of legumes in the cropping pattern excepting T-20 (bajra - mustard - oats - cheena) depleted the soil organic matter considerably.

Effect on Physical Properties of Soil:

The results of various multiple cropping sequences studied revealed that the physical properties of soil could be improved by the inclusion of feed and fodder crops in the rotation. However, the extent of their effect varied with the composition of the cropping patterns as noted earlier by various workers (Elson, 1940, 1943; Johnston, 1942; Silson and Browning, 1945; Wilson et al., 1947; Jish and Browning, 1948; Ilmstead, 1948; Strickling, 1957; Bolton and Weber, 1952; Mandal, 1956; Jones, 1961; Spratt, 1966; Malik, 1965 and Prabhakaran, 1970). The rotations comprising of legumes helped in improving the structure to a notable extent.

Inclusion of berseem in the cropping sequences reduced bulk density of the soils and slowed down the rate of infiltration but increased the percentage of water stable aggregates and water retention capacity (T-1, T-10, T-11, T-12, T-13 and T-14). The cultivation of other legumes like lucerne,
senji and cowpea in various combinations of crops also improved the physical condition of the soil to a considerable extent. This could be attributed to the nature of root system, soil microflora (Mishustin, 1945; Hubbel and Chapman, 1946) and root exudates (Azawa and Sekiya, 1956) available in the soil after cultivation of leguminous crops. Gupta and Sen (1962) reported that the highest aggregation of soil was due to the Rhizobium sp. A similar contribution made by legumes in different crop rotations was shown by Hide (1939), Johnston et al. (1942), Petroshinko (1949), Uhlam (1949), Hehar (1950), Acharya (1954), Fringale et al. (1956) and Harris (1966). Padma Raju (1967) suggested that it was desirable to include a leguminous crop like pea and berseem in a cropping sequence to preserve the structure of the soil. Prabhakar (1970) also reported that the physical properties of the soil were the best with legume crop in relay cropping trials at the I.A.R.I. farm.

The role played by a companionship of legume and grass (Pusa Giant Napier) in improving the physical properties of the soil was notable in treatments T-7 (hybrid napier - pea) and T-10 (hybrid napier – berseem). Similar beneficial effects of perennial herbage in improving soil structure was also reported by Henry and Newel (1947), Petroshinko (1949), Low (1950), Wehrile (1959), William and Cook (1961), William (1961) and Singh (1971). Moreover these findings also supported the data of Alderfer and Merkle (1941) which showed that bulk density values were inversely related to aggregate stability.

Hybrid napier grass in rotation T-10 and a mixture of maize+cowpea in T-11 and T-14 along with berseem were found to be the most effective in reducing bulk density of the soil and improving the soil aggregation. The complementary effect of leguminous roots could be advantageous to the grass roots. Moreover continuous supply of residues and protective
coverage by the napier grass and rapid decomposition of roots of *berseem*
or pea crops could be the possible reasons for these changes. Suchpromising results were also reported by Uhland (1957), Jablonski (1957),Tjag (1958) and Sirecki et al. (1961) and Singa (1971).

The presence of sorghum in the rotations reduced the impact of*berseem* and maize+cowpea and lowered the bulk density as could be observed in treatments T-12 (0.14) and T-13 (0.16). A similar effect of *najra* andsorghum was found in treatments T-12, T-13 and T-14 where these crops reduced the effectiveness of *berseem* and maize+cowpea in improving thesoil aggregation. The influence of rotations comprising of sorghum ontheprojective properties of the soil was studied by Deshpande (1953)and no significant difference in the degree of aggregation, volume weight,total pore space and percolation were observed in soils. Dakshinamurty (1966)reported that significant improvement of soil structure was observed whenthe green matter of sorghum and maize plants were incorporated into thesoil in sorghum - wheat or maize - wheat rotation. Swaminathan (1970)recommended that, if the stalks of maize were not needed for feedingcattle, their incorporation into the soil would help to improve the soilstructure. Judicious cropping together with proper feeding and tillagecould therefore help to improve soil productivity continuously.

The general trends of all the four indices of physical propertiesindicated that rotation T-5, sorghum (F) - oats (i) - maize+cowpea (F)and T-12 (sorghum - *berseem* - maize+cowpea) were keeping the soil in thebest condition while T-9 (lucerne) and T-14 (maize+cowpea - *berseem* - bajra)were making them poorest in this regard. Treatments T-1, T-11, T-15,T-16 and T-18 were in the next category while the treatments T-2, T-6,T-10, T-13, T-19 and T-20 were only a little better than the worst.
Treatments T-4, T-18, T-3 and T-17 were intermediate in their effects. Thus the treatments T-11 (maize+cowpea - berseem - maize), T-12 (sorghum - berseem - maize+cowpea) and T-18 (maize+cowpea - turnip - oats - maize+cowpea) may be considered good from both the points i.e. physical and chemical properties of the soil while T-2, T-13, T-14 and T-19 did not show encouraging results.

Economics of Various Cropping Patterns:

Cost of production:

The costs increased with the increase in the intensity of cropping. The sequences of two crops a year T-2, maize (G) - oats (F) and T-3, sorghum (F) - oats (I), cost Rs 3070 per hectare and Rs 3210 per hectare respectively while the cost of 3-crop sequences, sorghum (F) - oats (I) - maize+cowpea (F), was Rs 4150 (T-5) and that of maize - oats - maize+cowpea (T-6) was Rs 4280 per hectare. For four fodder crops a year the costs, as expected, were even higher (Rs 4820) for T-19 (baira - turnip - oats - maize+cowpea). These findings were in conformity with the ones reported by Swaminathan et al. (1970), Bains et al. (1972) and several other workers. The cost showed a rising trend with the inclusion of multi-cut crop like berseem which was harvested at least five times and was given about 13 irrigations during the period of its crop stand. For example, the treatment T-1, maize (G) - berseem (r), cost Rs 4040 per hectare as compared to T-2, maize (G) - oats (r), which cost Rs 3210 per hectare and hybrid napier intercropped with berseem in T-10 cost Rs 4510 i.e. about Rs 1140 more than T-7 comprising hybrid napier - pea (G).
Another factor that affected the costs of production was the sowing of summer crops like *bajra*, giving two cuts of green forage and requiring frequent waterings for its regeneration and luxuriant vegetative growth. The highest costs of production of Rs 5050 and Rs 4960 per hectare, caused by the presence of *berseem* in *rabi* and *bajra* in summer season, was, therefore, recorded in T-13 (sorghum - *berseem* - *bajra*) and T-14 (maize+cowpea - *berseem* - *bajra*).

Thus the results lead to the conclusion that (a) the costs of cropping patterns increased with the increase in their cropping intensity, and (b) the costs went up with the inclusion of multi-cut crops and the crops sown in summer with higher irrigation requirements.

**Net income as crop enterprise:**

Considering the net profits per hectare per annum from different cropping patterns, the 3-crop sequence, T-8, consisting of grain crops of maize, oats and *mung*, was found to be the most profitable, giving as high net returns of Rs 9700 per hectare, followed by treatment T-4 (Rs 8830) involving two grain and one fodder crops and T-6 (Rs 8450) with one grain crop and two fodder crops. This indicated that the replacement of grain crops with fodder crops in the sequences were responsible in bringing down the rate of profit from these cropping patterns. The presence of grain crops of oats, maize and sorghum in these sequences got them the highest income as was evident from per rupee return on cash expenses of oats (G) (Rs 6.19), maize (G) (Rs 4.81) and sorghum (G) (Rs 4.34). The net returns per day of crop stand was also the highest for these crops giving as high as Rs 31.6 for maize, Rs 26.31 for sorghum and Rs 25.00 for oats.
Higher market sale prices for end products of feed crops appears to be than the main reason for higher returns from such crop sequences/with fodders. The profits of these crop sequences were, however, well comparable with similar crop combinations of grain and fodder crops as reported by Bains et al. (1968), Swaminathan et al. (1970), Singh and Patel (1972) and Mathur (1972).

On comparing intercropping of hybrid napier with a feed crop of pea (G) in T-7 and a fodder crop berseem (T-10), it was observed that the former was superior with a margin of Rs 60 per hectare, though the cost of production of this combination was much lower than the latter. The profit per rupee spent on cultivation of hybrid napier was Rs 3.37, berseem Rs 2.20, while pea (G) touched the lowest value of Rs 2.54 of the grain crops. It may, therefore, be beneficial to adopt intercropping of perennial grass with legume fodder rather than a grain crop as this would maintain the supply of green forage to the market for sale for immediate returns to the producer. The results corroborated the earlier findings of M.D.R.I. (1968) and Singh (1971). Amongst fodder crop sequences involving 3-crops, T-14 (maize+cowpea - berseem - bajra) recorded the maximum net profit of Rs 6110 per hectare followed by T-13 (sorghum - berseem - bajra) with Rs 5990 per hectare. This small difference in the net incomes was possibly due to the slightly low per rupee profitability of sorghum (Rs 2.34) than maize+cowpea (Rs 2.44) while berseem and bajra had given profits of Rs 3.28 each on every rupee invested for their cultivation. Treatment T-19 involving four fodder crops of bajra, turnip, oats and maize+cowpea netted an income of Rs 6950 per hectare. Replacing bajra by maize+cowpea in a similar sequence T-18, the net income went down
by Rs 200 per hectare. This could be due to the fact that bajra (Rs 3.11) earned a per rupee return of Rs 0.67 more than maize+cowpea (Rs 2.44). The returns per rupee of cash investment for other crops i.e. turnip and oats (Dec. sowing) were Rs 4.14 and Rs 4.38 respectively. A short duration zaid crop of turnip was at par with early oats (with two cuts) in its highest net return of Rs 4.14 per rupee of investment. Treatment T-20 (bajra - mustard - oats - cheena) was found with the lowest net returns amongst 4-crop sequences since the corresponding crops of mustard and cheena obtained comparatively less returns of Rs 3.52 and Rs 2.06 for every rupee invested respectively than turnip and maize+cowpea (T-18 and T-19). Among the fodder crops the profitability per rupee of investment was the lowest in maize, giving as low as Rs 1.64 and Rs 1.90 for kharif and summer crops respectively. Thus the presence of this crop had brought down the over-all income of treatments T-11 (maize+cowpea - berseem - maize) (Rs 4800 per hectare) and T-17 (maize - senji - bajra) (Rs 3420 per hectare) which were the poorest of all the other 3-crop fodder sequences.

The conclusions emerging out of the cost and return analysis of cropping patterns are that (a) the crop sequences consisting of feed as well as feed and fodder crops possessed better income potential than of fodders only, (b) intercropping of hybrid napier with berseem fodder or pea (grain) fetched almost the same amount of net profit inspite of higher production cost of the former sequence and (c) inclusion of multi-cut and high yielding crops like berseem, bajra and oats in the cropping patterns fetched better monetary gains than maize or cheena.
Net returns through dairy enterprise:

Various economic factors determine the market prices of different feeds and fodders and their energy value is very seldom taken into account particularly in a country like ours, where not even a single green blade of grass is left unconsumed due to the chronic and acute shortage of feeding material. The returns from crop enterprise could not, therefore, be taken as an index of the income through dairying. The produce obtained from various crops has to pass first through another biochemical machine i.e. an animal, to produce human food, milk. The economic returns, thus depend upon the number of animals that could be sustained on the produce obtained from different crop combinations.

These results revealed that dairy farming either with buffaloes or cows had not much variation in monetary gains. However, the net returns were certainly affected by the yielding capacity of the animals; high yielding buffaloes and cows fetched better returns as expected than the low yielders. This trend was observed in all the cropping patterns. A crop sequence comprising of fodder crops of sorghum - berseem - bajra (T-13) netted an income of Rs 18740 per hectare with 8.8 buffaloes, each yielding 3,000 litres of milk per year or Rs 1320 per hectare with 11.1 cows with the same milk-yielding capacity. With buffaloes and cows having an average yield of 2,000 litres of milk per year, the per hectare returns were Rs 15040 and Rs 14520 respectively. The second best fodder-based sequence was T-19 with four fodder crops (bajra, turnip, oats and maize-cowpea) which gave a net income of Rs 17350 and Rs 17220 per hectare with high yielding and Rs 14530 and Rs 14510 per hectare with 2000 litres
milk-yielding categories of buffaloes and cows respectively. It is interesting to note that the carrying capacity for these crop sequences was the maximum. Thus the cropping patterns having both quality and quantity of feed and fodder could obtain better net returns through dairying. Similarly the intercropping system affected the income potential of the cropping patterns. Hybrid napier with pea (i) in T-7 was found more remunerative with net returns of Rs 17780 and Rs 17400 from 3000 litres milk yielders and Rs 14800 and Rs 13920 per hectare from 2000 litres milk-yielding buffaloes and cows than the combination of hybrid napier with berseem as an intercrop, since the former could meet the energy requirements for more animals than the latter. There was, however, one major drawback in this combination (hybrid napier with pea grain)—this could provide green forage for a limited period of the year since with the decline of temperature during the winter, hybrid napier ceased to grow and the pea (grain) occupied the field from November to April. Considering its utility and income, it would still be worth-recommending the combination for cultivation on a fraction of the area under fodder according to the requirements, so that at least the green supply could be utilized fully during scarce period along with its full monetary benefits.

Additional income through dairying:

The net additional returns that could be obtained through dairy business accounted for the final economic evaluation. The cropping patterns comprising feeds as well as feed and fodder combinations with the exception of one (hybrid napier intercropped with pea grain) were comparatively less remunerative as their income level was very low as compared to the fodder.
based sequences. None of these crop sequences could get an additional income of Rs 6000 per hectare even with the high-yielding milch cattle. Treatment T-8 comprising all grain crops (maize - oats - mung) proved inferior even to 2-crop sequence T-2 and a 3-crop sequence T-6, consisting of maize (G) - oats (F), and maize (G) - oats (F) - maize+cowpea (F) respectively. In other words, the additional income was found more with the inclusion of fodder crops in a cropping pattern or say, the fodder crops helped to fetch more returns to dairymen. These findings are in agreement with Raj and Mudgal (1963), Furi and Singh (1964), Mathur et al. (1967), Saran and Jackson (1967), Ahuja (1970), Mudgal (1971), Reiwani (1970), Sundaresan (1971), Patel (1971), Mehta (1971), Shankla (1972) and N.D.I.(1972).

Of the fodder crop sequences, the highest additional returns of Rs 12750 and Rs 12330 per hectare were recorded from buffaloes and cows each yielding 3000 litres milk per year respectively from a combination of sorghum - berseem - bajra that had shown the best net returns as a dairy enterprise also. It was thus evident that the fodder based sequences could provide attractive income even with their high costs of production, particularly if these were composed of the high yielding crops, rich in nutritive value as was evident from this cropping pattern.

**Economics and soil fertility status:**

Of the two treatments T-8 and T-4 with highest net income of Rs 9700 and Rs 8830 per hectare from crop enterprise, only T-8 consisting of all the grain crops of maize - oats - mung, was moderate in respect of changes in both the physical properties and organic matter and was, therefore, better than T-4, consisting of sorghum (G) - oats (G) - maize+cowpea (F), which caused a depletion of organic matter.
treatment T-12 (sorghum - berseem - maize+cowpea) which was found good from soil build-up, gave only Rs 5500 from crop enterprise. If these were turned into dairy enterprise on the other hand, the best ones from income point of view were T-7, T-13, T-19 and T-20 with net returns of about Rs 13000 to Rs 14500 per hectare but these appeared to lead to poor soil physical condition although T-7 and T-20 were comparatively better for changes in soil organic matter. Those considered best from long-term point of view/T-11 (maize+cowpea - berseem - maize); T-12 (sorghum - berseem - maize+cowpea) and T-18 (maize+cowpea - turnip - oats - maize+cowpea) which gave only moderate income of about Rs 4800 to Rs 6640 per hectare through crop enterprise and about Rs 11000 to Rs 11500 through dairy enterprise. In order to improve the fertility status of the soil under the cropping patterns earning high income, it would, therefore, be essential either to add organic matter through manures etc. or as recommended by Swaminathan (1970), the stubbles and straw of the crops should be incorporated into the soil to improve the soil structure in due course of time.

Employment potential:

The seriousness of the problem of under employment and unemployment in rural parts of India being well understood, a critical analysis of the relative employment potential of high yielding and nutritive fodder crops for maintaining good dairy cattle helped to raise the potential per hectare tremendously.

The problem could be looked into firstly as a crop enterprise i.e. if the crop produce was disposed off straight away from the field.
Crop enterprise:

The cultivation of multi-cut crops like berseem and hybrid napier in the cropping sequence was found to be the best in providing job opportunities to the idle rural population. An intercropping of these two crops in treatment T-10 had shown the highest potential, providing employment to as large a number as 321 man-days per hectare per year. This companionship of perennial grass with annual leguminous crop required high frequency of irrigation as well as harvesting operations which demanded more men per hectare. A combination of berseem (5 cuts) and bajra (2 cuts) with sorghum fodder in T-13 was the next best cropping pattern with man power requirement of 298 in a year. By raising the intensity of cropping from two crops a year to three crops a year, the increase in the number of man-days that could find wages for their living went up from 158 in T-3, sorghum (F) - oats (G) to 203 in T-5, sorghum (F) - oats (G) - maize + cowpea (F) and similarly from 205 man-days in T-2, maize (G) - oats (F) to 253 in T-6, maize (G) - oats (F) - maize + cowpea (F).

Thus an addition of one fodder crop in a sequence raised the employment potential by about 25 per cent. The cropping patterns with feed crops indicated better prospects of labour utilization than the fodder crops. Treatment T-4 with sorghum (G) - oats (G) - maize + cowpea (F), provided employment for 240 man-days while T-16 consisting of the same crops for fodder purpose, had jobs for 200 man-days. Similarly a 3-feed (grain) crop sequence T-8 with maize (G) - oats (G) - mung (G) raised the number of labour utilization by 50 per cent over a similar fodder crop sequence T-15 (maize - oats - maize + cowpea). Thus our results are in line with the earlier observations of Johnson (1968), Kanwar (1970), Beady and Aggarwal (1970), Swaminathan et al. (1970), Tandon and Dhondyal (1971),
Bains et al. (1972) and Chowdhury (1972) that intensive agriculture has great potential for providing employment to rural population of the country. In addition, the intercropping of high yielding nutritious grass with leguminous fodder like berseem recorded good opportunities for providing more man-days.

**Employment through dairy enterprise:**

These crop sequences when evaluated through dairy enterprise i.e. by raising dairy animals on the produce obtained from these crops for milk production, showed that dairy business had a tremendous scope to provide job opportunities. A cropping pattern involving sorghum – berseem – bajra (T-13) had an employment potential of more than 2300 man-days per hectare. This could support 8.8 buffaloes or 11.1 cows each yielding 3000 litres of milk per year or 10.9 buffaloes or 13.6 cows with milk producing capacity of 2000 litres of milk per year and had the potential to engage for full-time 2278, 2338, 1933 and 1964 man-days per hectare per year respectively. These figures included the man-power required in the process of raising crops as well as other day-to-day management operations at the Dairy farm. In other words, additional man-days that could get employment with dairy enterprise were 1980, 2030, 1635 and 1666 for the corresponding categories of milch animals respectively. Similarly a 4-crop sequence T-19 (bajra – turnip – oats – maize+cowpea) gave job opportunities for 2160, 2257, 1989 and 1957 man-days i.e. an additional employment for 1912, 2003, 1635 and 1703 man-days per hectare for corresponding categories C-I, C-III, C-II and C-IV of milch cattle over crop enterprise. An interesting point to be noted was that the low as well as high yielding categories of cows gave at least equal opportunities for employment potential as the buffaloes.
Thus the number of men that could find jobs on a dairy farm depended upon the herd strength and milk production capacity of the animals. As such the sequences with higher carrying capacity could offer better employment potentials. These findings on labour utilization of intensive cropping for dairy business not only supported the earlier estimates of Sundaresan (1970), N.D.R.I. (1971), Raut and Chugh (1971), Bains et al. (1972) but have also thrown some light on employment opportunities for farms with different species of milch cattle.

Thus, when we go in for utilizing the increased produce obtained through intensive systems of cropping through dairy enterprise in addition to the increase in the milk production potential of cattle, the employment potential also enhanced about 5 to 6 times. All these aspects are of utmost interest to the nation at the moment. According to the estimates for 1971-81 by the Expert Committee on Population Projections, as much as 69 per cent of our work force (approx. 208 million) will depend upon agriculture for employment even by 1981 and the social significance of a technological upgrading of the employment potential of our cropping systems through dairying is obvious.

Conclusion

The most important limiting factor in improving milk production in the country is the lack of adequate nutrition to the milch animals. This is why progress in improving milk production during the last 20 years has been relatively slow. Raj (1971) has shown that the sex ratios in the bovine animals in the different states of India are conditioned by the relative economic value of animals of a particular sex to the rural population. Thus in states where bullocks are important as sources of farm power, more male animals have tended to survive, while in states where milk production
is more important, females have become preponderant in the population. Differential feeding of calves seems to have been the mechanism determining the preferential survival of calves of one or the other sex. Both bullocks and cows need to be developed on healthy lines and for implementing the recommendations of the National Commission on Agriculture concerning dairy development, the scientific production of fodder and feed is a pre-requisite. The present study indicates that much can be done in this field.