DISCUSSION

The results on production potential of crops grown in sequences have exhibited interesting features in respect of yield of crops in Kharif (wet) and Rabi (dry) season, the overall performance of crops grown in sequence, the economics of raising crops in Kharif and Rabi as well as in double cropping sequences which have practical importance pertaining to crop production on rainfed uplands of Chotanagpur plateau.

The results (table 1.0) indicate that there have been considerable variations in yield of Kharif and Rabi crops as well as yield of crops in years during the period of investigation.

The yields of Kharif crops have varied considerably during the years of study. The mean grain yield of rice has been considerably higher in 1987-88 (first year) than in 1988-89 (second year). Such variation in rice yield has been probably due to differences in climate of the two years. The first year received 2082.7 mm of total rainfall while the second year experienced only 1188.1 mm. The Kharif season of first year has been exceptionally wet with the amount of rainfall amounting to 1832.4 mm during June to September which has been considerably higher than the rainfall registered for the same period in the second year (1029.2 mm). Ecologically rice is a semi-aquatic plant having higher water requirement ranging from 900 to 1300 mm amongst the cereals of similar duration (Verma, 1977). Therefore, it has been assumed that higher amount of rainfall distributed evenly during July to September, coinciding with the important growth stages viz, grand period of vegetative growth, flowering and grain filling the important critical stages of water needs, may have helped better manifestation of yield attributing characters consequent to higher yield in rainfed rice (Vamadevan and Murthy, 1978) during the first year.

On the contrary, maize and peanut, the other Kharif crops, have given higher yields in second year compared to the first year. More torrential rain in July, during the first year, coinciding with the initial growth stages of maize and peanut, may have resulted in initial setback to the crops. In the second year congenial amount of rainfall
in June and July, may have helped better emergence and initial establishment of maize and peanut, thereby resulting in higher yields in the crops. Unlike rice, maize and peanut probably cannot withstand higher amount of total precipitation during crop establishment for successive growth, development and grain yield (Singh, 1984). Therefore, these crops have recorded lower yields in the first year.

In general, the Rabi crops have performed better in the first year than in the second year. This may be due to the weather variation during the years. In the first year, the total precipitation during the period from October to March has been 196.5 mm as against only 83.6 mm in the second year for the same period. Thus it has been clearly observed that the amount of rainfall during October to March in the first year has been more than double that of the second year. Such favourable weather conditions, specifically the rainfall parameter, during the Rabi season of first year has been believed to have provided suitable moisture regime for sustaining growth and development of Rabi crops under rainfed upland conditions. It is of general agreement that limiting moisture in soil adversely affect the crops in Rabi season in rainfed uplands. It is also the general belief that the performance of Rabi crops in rainfed uplands depends mainly on the residual moisture storage capacity of the soil as well as on the amount of rainfall received during the crop season. Obviously, therefore, the higher amount of rainfall occurring in the Rabi season of first year has created favourable soil moisture regime which in turn may have promoted efficient physiological and metabolic processes during the early growth, flowering and grain development stages of most of the Rabi crops and supplied sufficient moisture for higher yields. Such favourable conditions due to higher amount of precipitation which creates congenial soil-moisture environment for efficient growth and yield of crops during Rabi season under rainfed upland conditions have also been reported by many workers (Malik et al., 1980; Grewal et al., 1984; Prasad and Singh, 1987).

Of the three crops in Kharif season, maize has shown higher production potential compared to rice and peanut. This may have been due to maize being a $C_4$ type plant having increased photosynthetic
efficiency at higher temperature prevailing in the season under plateau region. George and Prasad (1989) also have noted better production potential in Kharif maize compared to other cereals.

Considering higher production potential in maize under rainfed upland condition, Bagchi et al. (1990) have suggested that maize should be given priority over indigenous paddy or millets for sustainable agriculture in plateau region of Bihar. In this connection mention may be made of Mohapatra et al. (1984) who also have given due emphasis on maize cultivation in Bihar plateau. Thus, it is obvious that maize could help in stabilising production under moderately normal rainfall during Kharif season on upland conditions of plateau region.

Among the Rabi crops raised on Kharif fallow lands barley, chickpea and safflower have given considerably higher grain yields than that of lentil, linseed and toria. Linseed and toria have given fairly good yields than that of lentil. Lentil, however, has given the lowest yield during both the years. Such a wide difference in production potential of crops may have occurred due to genetic variability in plant species as well as their varied response to agro-climatic conditions. It is evidently seen that those crops which are capable of sustaining growth under deficient or low soil moisture regime have performed better while grown in rainfed uplands. Species and cultivars differ in their ability to survive or continue growing under conditions of water deficit (May and Milthorpe, 1962). In this context, selection of genetically desirable types that would better explore and exploit the soil for water and nutrient, deserve consideration (Russell, 1971; Hurd and Spratt, 1975).

It is clearly seen that chickpea and barley have emerged as most successful Rabi crops, followed by safflower, under rainfed uplands of plateau region. These crops have maintained consistently higher yields in both the years. Considerably stable yields of barley, chickpea and safflower in dry season may be attributed to their ability to extract more amount of moisture from deeper soil layers and comparatively less amount of transpiration from plant surface. Results of work done at IARI (IARI, 1970) have shown that crops like chickpea and barley are capable of extracting moisture to the extent of 26 and 24
per cent respectively from deeper soil layers. On the other hand, deep and extensive root system coupled with xerophytic nature of safflower have imparted drought tolerance and the ability to utilize soil moisture efficiently (Sharma and Verma, 1982). Safflower is considered as a drought resistant crop—(Knowles and Miller, 1965) capable of extracting moisture from deeper layers of 15-30 and 30-60 cm (Srivastava et al., 1985).

Linseed is comparatively a shallow rooted crop whereas toria is moderately deep rooted. These crops with their considerable power of soil moisture extraction have given fairly good yields under rainfed upland condition. It is interesting to note that among the Rabi crops, lentil has given considerably lower yield in both the years. Lentil is considered as a very hardy crop and its range of cultivation as regards climate is very wide. Inspite of this, by virtue of the deep root system, lentil has not been able to show reasonable yield in the season with fairly normal rainfall. Thus it is quite obvious that the poor yield of lentil may have been possible due to the acidic condition of the soil in the uplands of the plateau region. Singh (1983) has noted that acidic soils are not fit for growing lentil crop. On the other hand, high and stable yield in chickpea on upland conditions may have been due to more tolerance power of this crop against adverse weather conditions (Singh, 1984).

The results have indicated greater variation in production potential of different crops grown in Kharif and Rabi seasons. Production of crops is the result of co-ordinated interplay of hereditary factors and environmental conditions on the internal physico-chemical process of the plant. Environmental factors have no direct effect on genetic make up but they exert profound influence on the expression of its heredity (Sahu, 1972). Thus the variation in yields of different crops may be ascribed to the genetic make up of the individual crop species as well as the influence of environment in which the crop species is grown.

Thus, the results on performance of different crops grown in upland soils under the present set of experiments convincingly indicate the importance of crop selection for obtaining high and stable yield under rainfed condition in the plateau region. According to Russell
(1971), Hurd and Spratt (1975), selection of genetically desirable types that would better explore and exploit the soil for water and nutrients deserves consideration. Apparently it is suggestive that those crops which show fairly stable yields under the constraints of soil moisture should be considered for their inclusion in crop sequence particularly when the object of crop planning is to accrue monetary benefit from crop production on rainfed uplands.

A cursory look at the data in table 1.0 clearly reveals the fact that among rice, maize and peanut based cropping sequences, the maize based sequences, in general, have surpassed the physical output potential followed by rice based sequences. Such higher physical output noted in maize based sequences may have been due to higher production potential of maize itself. Higher production potential of maize over rice on rainfed upland conditions have also been reported by many workers (Mandal, 1962; Mahapatra et al., 1987). Peanut based sequences, however, have given lower physical output compared to maize and rice based sequences. This has been probably due to lower production potential of peanut, a C₃ plant type, where production potential is restricted on account of inefficient photosynthetic mechanism. There has also been greater variation in total physical output under each crop sequence in individual year irrespective of rice, maize and peanut based pattern probably on account of climatic variation in the two years. Such variation in yield of crops in Kharif and Rabi season in two years have already been discussed in previous paragraphs.

Data reveal that among the rice based patterns tried, rice-chickpea has offered by far the highest mean physical output in terms of total grain yields followed by rice-safflower and rice-barley. Lower yields have been recorded in rice-lentil and rice-toria sequences. Rice-linseed pattern has occupied the intermediate position. The high yields of the former three patterns are mainly due to better performance of crop species in Rabi under the edaphic conditions of plateau region. Lower yields from rice-lentil and rice-toria sequence may be due to the fact that Rabi crops grown in sequence following Kharif could not add much to total yield due to poor performance of the Rabi crops in rainfed upland. The results corroborate the findings of Bagchi
et al. (1990) who have reported that the total yield potential of rice-barley has been the highest followed by rice-linseed, rice-toria and rice-lentil. Chatterjee and Khan (1978) have reported that in rainfed uplands barley has given higher yield than lentil and linseed when grown after rice. Khan and Chatterjee (1986) also have reported that barley has yielded more than lentil followed by linseed after rice. Singh (1984) has also reported high yield potential of barley in rainfed uplands in Rabi. However, in the present set of experiment, rice-chickpea has given higher production potential than rice-barley. The rice-chickpea pattern has given maximum yield due to higher yield obtained from chickpea crop. But, Mahapatra et al. (1987) have reported that rice-chickpea has been less productive than rice-wheat sequence.

Among the maize based cropping sequences, the maize-chickpea pattern has been found to be more productive, followed by maize-safflower, than other sequences. In this context, citation may be made of Sharma et al. (1970) who have noted more production potential in maize-chickpea and maize-safflower over maize-linseed, maize-pea and maize-wheat sequences. Gite et al. (1987) in their study have reported that maize-chickpea sequence has been superior to maize-safflower in respect of production potential under rainfed lands. However, Mahapatra et al. (1984) categorically have pronounced safflower as a potential oilseed crop which is not grown at all for all practical purposes, except in a few land holdings in the plateau and sub-plateau region of Bihar, can be suitably included in the crop sequence, under rainfed lands when the object of the crop planning in these regions is to achieve maximum and stable yield. He has further reported that safflower has even a higher potential than linseed in dry season under rainfed condition.

It is interesting to note that many of the Rabi crops in peanut based sequences have given higher yields than the Rabi crops grown in rice and maize based sequences. In general, better performance of Rabi crops in peanut based sequence, may possibly be due to maintenance of soil fertility by taking legume crop in rotation (Sharma, 1987). Giri and De (1979) reported that a previous legume crop of
either peanut, cowpea or redgram have increased the yield of subsequently grown Rabi crops by improving soil fertility through symbiotic nitrogen fixation. Ramachandran (1989) has reported that yields of cotton, ragi and other cereals grown after peanut, have been 25 to 50 per cent higher than that obtained without groundnut in rotation.

Taking into account the peanut based sequences, peanut-chickpea has given higher mean yield followed by peanut-barley and peanut-safflower system, peanut-linseed and peanut-toria systems have occupied intermediate position. Both the systems have shown more or less similar performance in respect of physical output in terms of grain production. The peanut-lentil sequence has been the most inefficient among the systems. Higher total physical output in peanut-chickpea, peanut-barley and peanut-safflower systems may be accounted for high yields of chickpea, barley and safflower in respective crop sequence with peanut. On the other hand, linseed and toria could not match with chickpea, barley and safflower which have more potential in rainfed lands in dry season, resulting in lower physical output in peanut based sequences. The lowest yield in peanut-lentil pattern has primarily been due to inclusion of lentil which has probably been more vulnerable to acidic soil conditions of upland plateau region. Unlike other Rabi crops, lentil could not give reasonable yield when grown in sequence with peanut.

While considering the production potential of the cropping sequences, in general, it is clearly evident that maize-chickpea sequence has offered by far the highest average physical output in terms of grain yield under rainfed upland condition of plateau region. The maize-safflower pattern has followed next in order of physical output. Appreciably higher output of grains obtained under these two crop sequences over a period of two years may principally be accounted for higher production of maize in wet season as well as fairly high yields of chickpea and safflower in the dry season. This has been probably due to the better adaptibility and stability of chickpea and safflower in the dry season to rainfed lands.

The yield of by-products (table 1.1) that has been derived from the crops under varied crop sequences reveal conspicuous variation. Efficiency in manifestation of by-products has been higher in wet
season crops. Higher magnitude of by-product yields of wet season crops over dry season may be attributed to the luxuriant growth of Kharif season crops under congenial conditions of soil moisture and season. Among the wet season crops of rice, maize and peanut, maize has revealed its efficiency in higher by-product dry stalk production owing to its intensive growth habit probably on account of C₄ mechanism in the species. Better manifestation of by-product yield of Rabi crops in the first year may be accounted for efficient physiological growth due to more favourable soil moisture regime on account of higher amount of rainfall received during the crop season. There has been considerable variation in by-product yield of crop sequences during individual years due to variation in rainfall receipts during the years of study. However, maize-safflower, maize-chickpea, maize-toria and maize-linseed systems have shown their efficiency in higher by-product production owing to their better vegetative growth under the edaphic conditions of plateau region. The lowest dry stalk production in rice-lentil and rice-toria systems may be accounted principally for short stature and poor growth of lentil and toria as well as comparatively low dry matter production efficiency of rice compared to maize.

Maize equivalent yields (table 1.2) have varied considerably from season to season as well as year to year due to variation in climate and other environmental factors. Appreciably higher maize equivalents in Kharif than in Rabi may be accounted for higher yields of crops due to higher amount of rainfall received in Kharif than in Rabi season.

Maize and peanut based sequences have given higher maize equivalents in Kharif of second year due to higher yields of maize and peanut as has been explained while discussing the yields of these crops in earlier paragraphs. Similarly, lower maize-equivalents in Rabi of second year may be attributable to relatively low rainfall in the season which have affected adversely the yield of crops. Higher maize-equivalents in maize and peanut in Kharif may be attributed to higher yields of crops as well as higher monetary values of the crops. The results further reveal that among the different cropping sequences, maize-chickpea, peanut-chickpea and rice-chickpea have resulted in higher maize equivalents which may be accounted for
higher yields of component crops as well as their higher monetary values. The results thus clearly indicate that inclusion of chickpea in the sequences have been most productive in terms of maize equivalent yields.

It is evident (table 1.9) that there has been considerable variation in production efficiency of cropping sequences in the years probably due to variation in climate of two years. Higher production efficiency in rice based sequences in first year may be accounted for higher yield of rice in Kharif as well as higher yields of Rabi crops due to higher amount of rainfall in both the seasons. Lower production efficiency in peanut based sequences as compared to rice and maize based sequences may principally be attributable to lower production potential of peanut itself. Maize based sequences, in general, have shown higher production efficiency over rice and peanut based sequences, excepting rice-chickpea and rice-toria system. In rice-based sequences, inclusion of either toria or chickpea has resulted in higher production efficiency of the sequence. Similarly, toria or chickpea when grown after peanut in peanut based sequence, may have given comparatively higher production efficiency in the sequence. However, among the cropping sequences tried, maize-toria has proved to be most efficient followed by maize-chickpea probably on account of higher yield obtained from short duration (95 days) maize as well as higher stable yields of Rabi crops grown following maize. Significantly highest production efficiency in maize-toria sequence may be attributable to minimum total duration of the system. Thus the results convincingly indicate that for achieving higher production per unit area per year from a crop sequence, it would be ideal to include maize in Kharif and toria or chickpea in Rabi in rainfed uplands of plateau region.

The economics of production of individual crops and in sequence of cropping over a period of two years reveal considerable variation in gross returns (table 1.4) from Kharif and Rabi crops as well as from sequences probably on account of variation in yield of individual crops and crop sequences in both the years. In rice based sequences, rice-chickpea and rice-linseeds pattern have given higher gross returns. Among maize based sequences, maize-chickpea and maize-toria have
been most remunerative. Similarly, among peanut based sequences, peanut-chickpea and peanut-toria have been more profitable in terms of gross return. Appreciably higher return from these sequences may have been due to higher physical output as well as higher selling price of the products. Inclusion of Rabi crops other than chickpea, linseed and toria in rice, maize and peanut based sequences have resulted in lower gross return mainly due to lower yields of Rabi crops in such sequences.

It is noteworthy that inclusion of lentil in sequential cropping has resulted in comparatively lower gross return from rice, maize or peanut based sequences. Growing of lentil, following Kharif crop in sequence, has been most uneconomic due to meagre yield of lentil in acidic upland soil condition of plateau region.

The results clearly reveal that maize-chickpea, rice-chickpea and peanut-chickpea systems have been most remunerative compared to the other sequences. Inclusion of chickpea may have been the contributing factor towards higher gross return from these sequences due to high stable yield as well as high market value of the produce. Therefore, the results on different cropping sequences under the present set of experiments in rainfed upland conditions of plateau region certainly indicate that chickpea grown in succession under double cropping would offer higher gross returns.

Considerable variation in net returns (table 1.7), from individual crop and in sequences during the years, have been mainly due to variation in yield of the crops as well as variation in costs of cultivation. Among the cropping sequences taken under consideration, rice-chickpea, maize-chickpea and rice-linseed have recorded higher net returns per hectare in the first year which may be accounted for higher total yields resulting in high monetary return from the system. In the second year, crop sequences like maize-chickpea, peanut-chickpea and rice-chickpea have given appreciably higher net returns. The results clearly indicate that inclusion of lentil in double cropping systems with rice, maize and peanut has rendered the sequences uneconomic in terms of net return probably due to lesser contribution to the yield by lentil under the agro-climatic conditions of plateau.
region. It is interesting to note that raising barley and lentil, in the Rabi season of second year, have incurred greater monetary loss. This has been probably due to the fact that the cost of cultivation of these crops exceeded the value of produce. Poor yield of the crops consequent to lower monetary returns may have been the reason for such loss in the Rabi season of second year.

Comparing the net returns from the different cropping sequences, over a period of two years, maize-chickpea has proved to be most efficient followed by rice-chickpea and peanut-chickpea. These sequences have also been found to be significantly superior to the rest of the patterns. The high net returns of these patterns have been evidently due to the higher production potential of chickpea, a legume crop, compared to other Rabi crops such as barley, lentil, linseed, safflower and toria.

Appreciably higher stable yield and high value of chickpea may have compensated for the higher cost of cultivation than that of other Rabi crops thus contributing significantly towards higher net returns from the sequences involving chickpea. It is thus suggestive of the fact that the farmers with sound economic footing may be advocated to adopt the maize-chickpea sequence under rainfed upland conditions of plateau region.

The results further reveal notable relationship between the type of crops grown in Kharif and Rabi and their returns per rupee of investment on cultivation of the crops taken in double cropping system as adopted under the present experimental conditions. Greater variation in cost-benefit ratio (table 1.8) of crops and of sequences in years have been attributable to their variation in yield potential, value of produce and cost of cultivation. However, crops like rice, chickpea, linseed and toria have recorded higher average cost-benefit ratio (more than 2) than that of maize, peanut, barley, lentil and safflower in respective seasons of their cultivation. This has been due to higher returns over the investment per hectare in cultivation of the former crops while the returns have been considerably low in other crops. Among the crop sequences, rice-chickpea has offered by far the highest cost-benefit ratio. Maize-chickpea comes next in order.
The rice based sequence consisting of safflower, linseed and toria and maize based system with linseed and toria have given higher cost-benefit ratio (more than 2) than peanut based sequences with chickpea and toria. Though the rice-chickpea system has given higher cost-benefit ratio, the net return per hectare per year has been lower than that of the maize-chickpea system. This probably has been due to higher investment per hectare per year in case of maize-chickpea system. Thus it indicates that the net income from a cropping system has not been directly proportionate to the capital investment but it is influenced by the market demand for the crop and its commercial value. Comparatively low cost-benefit ratio (less than 2) obtained in maize-lentil and peanut-lentil systems may be principally accounted for higher cost of cultivation but lower net income from the sequences under study. The cost of cultivation of these sequences has been quite high but the net profit is marginally higher than the capital investment which may have resulted in low cost-benefit ratio. Selection of crops for double cropping system, therefore, must mesh in a crop sequence to give a maximum return from production and resource use over the year in rainfed lands.

The results on production potential of crops under the present set of experiments, thus clearly point out the ample scope for increased agricultural production as well as monetary returns through double cropping by adopting suitable crop sequences on rainfed upland conditions. Thus there is a greater possibility of increasing crop intensity to 200% through double cropping by which the production would be increased to 31.79 per cent. Correspondingly the net return could also be enhanced by 1.46 times higher from per rupee investment in rainfed uplands of plateau region. Furthermore, the results of the present investigation convincingly indicate that for achieving higher production per unit area per year the ideal double crop sequence should consist of maize or rice in the Kharif season and chickpea in the Rabi season under rainfed upland conditions of Chotanagpur plateau region.

The entire results of the study have been in favour of "double cropping" which may emerge as a potential possibility of increasing
production of cereals and pulses, in particular, from rainfed areas to boost the production per unit area and to get adequate returns.

The possibilities of double cropping have also been reported by Shrivastava and Singh (1973) with the inclusion of early maturing Kharif rice followed by deep rooted linseed in rainfed uplands of Chotanagpur plateau. Tiwari and Bisen (1975) experimenting on rainfed farming of central wheat zone of Madhya Pradesh concluded that the soyabean-safflower sequence have been most productive. According to Srivastava and Singh (1979), urid-mustard and urid-gram sequences have been most remunerative under rainfed lands of Udaipur in Rajasthan. Masood Ali (1978) has suggested the use of Kharif fodder crops or short duration grain sorghum and Kharif pulses followed by Rabi grown crops for rainfed areas. Anonymous (1980) and Singh et al. (1980) also have reported in favour of "double cropping" having higher potential possibilities over monocropping in rainfed areas.