The present study of phytosociology of wheat field on two study sites revealed that the maximum number of weed species was 26 on site I. In rice field, the maximum number of weed species was 23 recorded on site I. In wheat crop, maximum density of weeds was recorded in the month of February while in rice crop maximum density of weeds was recorded in month of August. In wheat field, maximum density of 145 plants/m² was recorded on site I and minimum of 70 plants/m² on site II. Similarly, in rice field also maximum density of weeds was recorded on site I (134 plants/m²) and minimum (61 plants/m²) on site II.

The wheat field species like Anagallis arvensis, Convolvulus arvensis, Cirsium arvense, Dichanthium annulatum, Digera muricata, Fumaria indica, Gyandropsis gynadra, Launaec ecaulis, Medicago polymorpha, Polygonum plebeium, Rungia pectinata, Verbascum chinense, Vicia hirsuta and vicia Sativa were present only on site I. In rice field also species like convolvulus arvensis croton bonplandianum, Echino chloa crussgalli, Salvia plebeia, Scoparia dulcis, and Sphearanthus indicus were present only on site I. It is quite apparent that there is a major difference in the weed flora of wheat and rice fields, because
they are Rabi and Kharif crop respectively. The characteristic feature of weed is that they possess some sort of periodicity in germination which mainly depends upon seed dormancy and, definite temperature requirements for germination. Brenchley and Warington (1930) observed the germination of 36 common arable weeds by keeping field soil in shallow pans in a glass house for over a period of three years. Out of those 11 germinated in autumn (September to December), 9 in winter (January to March) while the rest 16 showed no periodicity germinating either at irregular intervals or throughout the year. This periodicity is responsible for the association of certain weeds with certain crop. Tripathi (1965) observed that *Anagalis arvensis*, *Asphodelus tenuifolius* *chenopodium album*, *Euphorbia dracunculoides*, *Phalaris minor*, *Vicia hirsuta* and *Vicia sativa* are some of the Rabi weeds which are not all represented in kharif weed flora, perhaps because of the possession of only one germination peak.

There are some weeds like *Ageratum conyzoides*, *Alternanthera sessilis* *Amaranthus spinosus*, *Amaranthus Viridis*, *Agremone mexicana*, *Chenopodium album*, *Melilotus alba* *Phalaris minor*, *Rumex dentatus*, *Solanum nigrum*, *Tephrosia purpurea*, *Trigonella foenumgraecum*, *Visia hirsuta* and *Verbascum chinense* were present only in wheat field and absent in rice fields similarly weeds like, *Surplus martimus* *Paspalum paspolodes*, *Saggiteria pygmeae*, *potamageton distinctus*, *Eocharis spp. Echinochloa crusgalli*, *Eclipta alba*, *Celosia argentina*, *Sciopus spp.*, *Sctaria gluca*, *Monocharia spp.* were found only in rice field and were absent in wheat fields. The common weeds of both wheat and rice crop fields differ in their frequency and density. The variation in the species composition of different sites is due to local edaphic and biotic interactions. Because of site I the soil moisture content, the organic matter content and total nitrogen were higher than on the site II. Besides this biotic disturbance was least at site I.
In wheat field, the most dominant weed was *Phalaris minor* in both study sites with 100 percent frequency. Its density and importance value index were found to be very high on both study sites. In site I there are a number of weeds like *Ageratum conyzoides, Amaranthus Spinosus, Amaranthus viridis, Anagalis arvensis, Chenopodium album, Cyperus rotundus* *Cynodon dactylon, Euphorbia hirta, Melilotus alba* and *phalaris minor* which show frequency values of 70 percent or above in one or more months. In rice field, the most dominant weed was *cyperus rotundus* with 100 percent and 90 percent frequency on site I and II, respectively. The density and importance value index of this weed was also found to be very high on both study sites. In rice field, there are a number of weeds in site I which show frequency value of 50 percent or above in one or more months, e.g. *Cynodon dactylon, Cyperus rotundus setaria glauca & Eclipta alba*.

In wheat field the common weeds were *Ageratum conyzoides, Amaranthus spinosus, Amaranthus viridis, Argemone maxicana Chenopodium album, Euphorbia thymifolia, Euphorbia hirta, Echinops echinatus, Melilotus indica, Phalaris minor, Rumex dentatus, Salvia plebeia, Solanum nigrum, Trianthema portulacastrum, Verbascum Chinense, Vicia hirsuta* and *Vicia sativa* in both study site I and II with high frequency and density.

In rice field the common weeds were *Celosia argentia, Convolvulus arvensis, Cynodon dactylon Echinochloa colonum, Monocharia spp., Melilotus alba, Cyperus rotundus, Eocharis spp., Paspalum paspalodis, Potomogeton distinctus Surplus maritimus, saggitata pygmaeae, Sciopus spp. and Setaria glauca* in both study sites I & II with high frequency and density.

Biomass increment has been estimated separately for plant parts such as leaf stem, fruit and root in case of rice and wheat crops. The peak value of rice leaf biomass was noted to be 74.3 g/m² at age of 75 days and upto this age the leaf biomass continued to be greater than that of stem biomass, but after 75 days
the stem biomass superseded it and reached a maximum biomass of 320.88 g/m² at the age of 105 days. Maximum value of fruit biomass (160.20 g/m²) was found at the age of 105 days. The biomass of root of rice followed the increasing trend up to 120 days and maximum value was only 40.60 g/m². The rice crop plants attained their peak biomass value 584.94 g/m² at the age of 120 days. The biomass of rice crop increased up to 120 days age. But the fractionated biomass of vegetative parts started decreasing after 75 and 105 days. The rate of increase in fruit biomass, however compensated the loss in biomass of vegetative parts to some extent. For rice maximum value of the productivity of leaf was 2.20 g/m²/day at age of 75 days, for stem was 7.66 g/m²/day at age of 105 days ad for its fruits maximum rate of production was between 105 to 120 days of age. Root productivity also increased up to 75 days. The negative values for stem productivity was recorded after 120 days age. The productivity of rice crop as a whole increased continuously up to 120 days and the maximum rate of production 12.81 g/m²/day was found between 105 to 120 days age.

Like rice crop biomass increment has been estimated separately for wheat plant parts such as leaf, stem fruit and roots. Initially the biomass of leaf up to 75 days was greater than that of stem and root but on later the stem biomass superseded the leaf biomass. Maximum biomass of leaf was 100.82 g/m² at the age of 75 days. Maximum biomass of stem (543.2 g/m²) is recorded at 105 days age. Fruit biomass began rising from 75 days age and reached the maximum of 112.82 g/m² when the crop plant entered the senescent stage. The biomass of roots followed the increasing trend up to 105 days. It reached its maximum biomass value of 80.20 g/m². The maximum biomass of wheat crop was at the age of 105 days (827.70 g/m²). In wheat crop the increasing trend was observed up to 105 days age, but when we look to fractionated biomass data, we find that leaf biomass
started decreasing after 75 days and the stem & root biomass after 105 days. The increase in fruit biomass however compensated the loss to some extent.

The percentage contribution leaf of wheat was very high in the initial stage but later stem overtakes it due to rapid increase in the stem biomass. After 60 days the percentage contribution of stem suprassed that of leaves. The increasing trend continued upto age of 120 days. Increasing trend in the percentage contribution of fruit and root was observed up to the age of 120 and 60 days, respectively. For wheat maximum value of productivity of leaf was 2.08 g/m$^2$/day at the age of 60 days, for stem was 13.46 g/m$^2$/day at age of 105 days and for its fruit maximum rate of production was between 105 to 120 days of age. Increasing trend was also observed in root productivity up to the age of 75 days. The negative value for stem and root were recorded after crop as a whole increased continuously upto 75 days and the maximum production rate to 15.83 g/m$^2$/day was found between 60 to 80 days. After this the production rate falls down.

Biomass and production rate of the wheat and rice croplands under unweeded and partially weeded croplands when compared with that of fully weed cropland, it is observed that the general trend of production rate is the same in all the three conditions, but the production values are much higher in fully weeded fields. The peak biomass of wheat 1210.98 g/m$^2$) and rice (918.40 g/m$^2$) crops in fully weeded fields was much higher than the combined biomass of crop plus weed in the unweeded croplands of wheat (979.30 g/m$^2$) and rice (815.62 g/m$^2$). In unweeded wheat fields the weeds have accounted for about 17 percent of the total production while in case of rice field 28 percent to the total production, when the crop biomass was at its peak.

Stahler (1948) observed that light is the prime factor around which competition factors develop. Similar observation has also been made by Moomaw et.al. (1966) and Singhlacher et.al. (1978). The peak value of wheat leaf biomass
(210.17 g/m²) and rice (112.67 g/m²) in fully weeded cropland was much higher than the peak value of leaf biomass of wheat (102.0 g/m²) and rice (74.30 g/m²) in an unweeded condition. A high leaf biomass in fully weeded condition is conducive to higher production rate through greater photosynthesis and therefore net accumulation of organic matter is higher in fully weeded croplands. Singh (1978) has also made similar observation of high production rate accompanied by higher leaf biomass in Zizyphus Jujuba in a savanna stand.

In fully weeded croplands fruit biomass of wheat (203.20 g/m²) and rice (352.0 g/m²) is much higher than fruit biomass values of unweeded fields of wheat (129.4 g/m²) and rice (15.6 g/m²) crops. So the increase in fully weeded condition was 73.8 g/m² in case of wheat ad 156.4 g/m² in case of rice.

Percentage fruit yield of wheat and rice in an unweeded cropland as compared to that fully weeded condition was only 63.7 percent and 55.6 percent , respectively. So the loss in fruit yield due to weed infestation in wheat was 36 percent and in rice field 44.4 percent . In rice field the crop plants are taller than the weeds whereas in wheat fields some weeds are taller than crop and this may explain a greater percentage loss of fruit biomass in wheat than in rice.

Weber and Staniforth (1957), Moolani ad Slife (1960) and Moolani et.al. (1964) observed that more severe yield reduction in beans were due to pigweeds Amaranthus hygridas L. which overtopped for seriously sheaded the crop plant and thus affected assimilation processes. Aspinall and Milthorpe (1959) reported that a reduction in dry weight and tillering of barley occurred directly from the shading of the lower portion of the culms. Partially weeded fields of wheat and rice crop in which only Chenopodium album and Cyperus rotundus were allowed to grow respectively and their uniform density was maintained, the trend of biomass increment was similar to that of an unweeded cropland. In this
case values are greater than unweeded fields but lower than fully weeded croplands.

In the partially weeded condition about 12 percent of the total biomass in wheat fields and 15 percent in rice fields are shared by weeds when the crop biomass was at a peak. Fruit biomass of both wheat (152.6 g/m²) and rice (240.3 g/m²) was also higher than unweeded fields but lower than fully weeded croplands. In this experiment the loss in fruit production in comparison to fully weeded cropland in wheat field was about 25 percent and in rice field it was 31 percent.

In an unweeded cropland of wheat the percent loss in fruit production was 56 percent. As shown earlier the loss caused by only two dominance weeds Phalaris minor and Chenopodium album is 25 percent. Similarly compared to 44.4 percent fruit biomass loss in unweeded rice fields the loss caused by Cyperus rotundus and Cynodon dactylon alone in partially weeded field is 30 percent. So in both the crop fields these two species are among the most important weeds responsible for such a heavy reduction in biomass.

Statistically bivariate analysis of variance of biomass data of both the crops in relation to age and weeding conditions was carried out and variance ratio ‘F’ was found to be significant at 1 percent and 5 percent. (Table 8.1 and Table 8.2). Percentage reduction in crop yield as a result of weed infestation has been estimated by many workers. Pavlychenko and Harrington (1935) observed a reduction of 40 percent in the yield of wheat grown in plots infested with wild mustard as compared to the weed free plots. Crowber (1943) found a 30 percent reduction in the yield of cotton seeds where the weeds were allowed to grow for two months. Gleason (1956) has shown that maize yielded 73 bushels, in wet tropics of Mexico, when kept weed free all the season, as compared to only 10 bushels when weeds were left during the entire season of the crop produce.
Chaugule and Khuspe (1957) working on ground and fodder Jowar, observed a loss of 49.5 percent in the yield of the former in the presence of weeds. Staniforth (1957) also obtained a significant reduction in the yield of maize and soyabeans. Knake and Slife (1962) reported yield reduction of 25 percent for corn and 28 percent for soyabeans due to competition effects of giant fox tail, *Setaria feberii*, growing in association with crops. Tripathi (1965) also reported reduction in yield of wheat and gram as a result of weed infestation. The biomass percentage contribution of fruits in fully weeded cropland was higher than in the partially weeded and unweeded conditions in both the crop fields of mustard and gram. In case of mustard, the maximum contribution of fruit biomass (to total biomass) in fully weeded cropland being 18.13 percent, followed by partially weeded condition (17.22 percent) and least in an unweeded cropland (16.79 percent).

In the same way in the rice field maximum contribution of fruit biomass (18.33 percent) was in fully weeded croplands followed by partially weeded (34.05 percent) condition and least in unweeded cropland (33.68 percent).

The maximum rate of dry matter production of weeds in an unweeded cropland of wheat was 3.85 g/m²/day between 60 to 80 days when the crop plants were in flowering stage. After that the rate decreased to 1.98 g/m²/day partly due to the disappearance of some of the weeds as well as litter fall and partly due to senescence. In wheat also the maximum rate of 15.83 g/m²/day was found between 60 to 80 days of age.

In rice field the maximum rate of production of weeds 6.10 g/m²/day in an unweeded cropland was found between 80 to 100 days. During this period rice crop was also in flowering stage. After 100 days negative difference in successive biomass values was obtained for weeds as the temperature in the month of October falls and most of the weeds enter senescence and than become dried. The maximum rate of production of rice was 12.81 g/m²/day between
Table 8.1

Bivariate analysis of variance of biomass value (kg/m²) of Wheat crop in relation to different age and weeding conditions.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degree of freedom</th>
<th>Sum of squares</th>
<th>Mean sum squares</th>
<th>F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>5</td>
<td>2.81</td>
<td>0.562</td>
<td>62.44*</td>
</tr>
<tr>
<td>Weeding conditions</td>
<td>2</td>
<td>0.10</td>
<td>0.05</td>
<td>5.56 **</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>0.09</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 1%
** Significant at 5%

Table 8.2

Bivariate analysis of variance of biomass value (kg/m²) of Rice crop in relation to different age and weeding conditions.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degree of freedom</th>
<th>Sum of squares</th>
<th>Mean sum squares</th>
<th>F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>6</td>
<td>1.80</td>
<td>0.30</td>
<td>50.0 *</td>
</tr>
<tr>
<td>Weeding conditions</td>
<td>2</td>
<td>0.053</td>
<td>0.03</td>
<td>5.0 **</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>0.067</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>1.920</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 1%
** Significant at 5%
100 to 120 days. Comparing the rate of production of unweeded croplands with that of fully weeded, it was observed that the rate of production in fully weeded cropland is very high as its maximum rate for wheat crop is found to be 24.39 g/m²/day between 60 to 80 days. This is higher than the combined productivity of 19.69 g/m²/day for wheat and weeds in unweeded condition. Similarly in case of rice the maximum production rate of 23.62 g/m²/day in fully weeded condition was distinctly higher than 12.36 g/m²/day rate of combined productivity of crop and weed in an unweeded condition.

In partially weeded condition the rate of production of wheat and rice was higher than in unweeded condition but lower than fully weeded condition. The maximum rate of production of wheat crop was 20.45 g/m²/day between 60 to 80 days and of weeds was 2.49 g/m²/day at the same age. Similarly in rice field the maximum rate of production of crop was 17.02 g/m²/day between 100 to 120 days while that of weed was 4.37 g/m²/day between 80 to 100 days.

There was also a sharp increase in the rate of production of fruits in fully weeded fields. In an unweeded cropland of wheat the maximum rate of fruit production was 2.64 g/m²/day between 80 to 100 days, while in partially weeded fields the maximum rate was 3.75 g/m²/day and in case of fully weeded condition it was 5.46 g/m²/day between 80 to 100 days.

Similarly in rice field also the rate of production of fruit increased significantly from unweeded to fully weeded field. In an unweeded field it was 5.24 g/m²/day between 100 to 200 days while in case of partially weeded fields the maximum value was 6.88 g/m²/day at the age and in the case of fully weeded fields the peak value rises up to 9.75 g/m²/day at the same age. The percentage reduction in the rate of production (g/m²/day) of crop in an unweeded field of wheat in comparison to fully weeded field was 35 percent while in partially weeded field it was 16 percent. In case of rice crop the percentage reduction in the
rate of production was higher than wheat crop in an unweeded field in comparison to fully weeded croplands. The reduction values were 54 percent in an unweeded field and 27 percent in partially weeded field. The higher rate of reduction in rice crop may be due to better growth performance of weeds in rice fields.

It is quite evident from the discussion of computed data that the weeds have caused a significant reduction in the yield of wheat and rice crop as well as of the total primary production of the crop ecosystems.

The present investigation entitled “Comparative ecological studies of Kharif and Rabi crop ecosystems at Rameshwar, Varanasi” was carried out at the research farm of the village Rameshwar and Rameshwar Goshala, Varanasi, during the Kharif seasons of 1997 and 1998 on rice and wheat as succeeding crop in Rabi seasons during 1997-98 and 1998-99 with the a view to study and assess the effect of nitrogen, phosphorus and potassium on rice and wheat crops.

The soil of the experimental field was sandy loam having low status of nitrogen and medium status of phosphorus and potassium. The experiment was laid out and conducted in $3^2 \times 2$ factorial partially confounded design. The treatments comprised of three levels of nitrogen (40, 80 and 120 kg/ha), three levels of phosphorus (0, 40 and 80 kg P$_2$O$_5$/ha) and two levels of potassium (0 and 40 kg K$_2$O/ha) in addition to one absolute control (N$_0$P$_0$K$_0$) in each block. The eighteen treatment combinations along with the absolute control were replicated four times. Urea, single super phosphate and muriate of potash were used as sources of fertilizers in both the crop. Half of the nitrogen and the entire quantities of phosphorus and potassium were applied at the time of transplanting of rice and sowing of wheat; the remaining nitrogen was top dressed in two equal amounts at the interval of one month after transplanting in the case of rice and after sowing in the case of wheat. Rice was transplanted on 16$^{th}$ and 11$^{th}$ July, while wheat was sown on 22$^{nd}$ and 17$^{th}$ November, respectively in two years. Transplanting of rice
utilizing 25 days old seedling was done after puddling, while wheat was sown in the field prepared after pre-sowing irrigation to maintain uniform moisture at the start of experiment. In both the years the seed rate was maintained at 100 kg/ha. Jaya, the most popular variety of rice and HD (M) 1553 variety of wheat were used in this study. All the standard measures of agronomic package of practices were performed from time to time up to maturity of the crop.

To study the nitrogen, phosphorus and potassium requirement of rice and wheat crop growth observation, viz., height of the plant and number of total tillers per m² were recorded one week prior to the harvest of the crop. Yield and yield attributes, viz., number of effective tillers per m², length of panicle in rice and ear in wheat, total number of grains per ear, filled grains per panicle in rice and per ear in wheat, sterile grains per panicle, thousand grains weight and yield of grain and straw per hectare were determined after the harvest of the crop. Grain yield response and magnitude of response at various levels of nitrogen, phosphorus and potassium of rice and wheat were worked out. Economics of rice and wheat cultivation were also worked out taking mean values obtained from the data of the two years. The plant samples (grain and straw of rice and wheat) obtained at harvest were chemically analysed for determining total nitrogen, phosphorus and potassium. The removal of nitrogen, phosphorus and potassium (kg/ha) were calculated accordingly. The soils of experimental plots were sampled after completion of each crop cycle (Rice-wheat) and were analysed for total nitrogen, available phosphorus and available potassium. An attempt was also made in addition to present an approximate balance sheet of total nitrogen, available phosphorus and available potassium after each crop cycle (Rice-wheat) during both the years.

Every additional dose of nitrogen increased the plant height of rice and wheat significantly up to 120 kg N/ha over the control. However in wheat 30
and 120 kg N/ha were found at par. Similarly, 40 and 80 kg P\textsubscript{2}O\textsubscript{5} recorded significant differences over the control but were at par among themselves. No significant effect of potassium was found. Significant increase in total number of tillers/m\textsuperscript{2} was found 120 kg N/ha over the control in rice and wheat. But in rice plant significant differences between 120 and 80 kg N/ha were not noticed. Application of 80 kg P\textsubscript{2}O\textsubscript{5}/ha recorded significant increase in total number of tillers/m\textsuperscript{2} over the control in both the crops. Minor increase in total number of tillers due to potassium application was found. Number of effective tillers increased significantly with each level of nitrogen over the control in both the crops. However, during the first year in rice and in the second year in wheat 80 and 120 kg N/ha was found at par. Application of 40 and 80 kg P\textsubscript{2}O\textsubscript{5}/ha recorded significantly higher number of effective tillers over the control plot, but were found at par. This trend was noted in rice in both the years and in wheat crop only during the second year. The first year of wheat crop recorded significant differences at all the three levels of phosphorus. No effect of potassium was observed.

Length of panicle in rice and ear in wheat measured significant difference with each increment in the levels of nitrogen over the control. But in rice only 80 and 120 kg N/ha were found at par. None of the phosphorus levels were found significantly superior in rice crop. On the other hand, ear length increase significantly upto 80 kg P\textsubscript{2}O\textsubscript{5}/ha in both the years. In the second year such a difference was noted only between the control and 80 kg P\textsubscript{2}O\textsubscript{5}/ha. Potassium had no significant effect either on panicle or ear length. Each level of nitrogen significantly increased the number of filled grains per panicle in rice and per ear in wheat upto 120 kg N/ha. but 80 and 120 kg N/ha was found at par. At the control and 40 kg N/ha levels higher number of fertile grains/panicle were observed in the first year while it was more during the second year at 80 and 120 kg N/ha. In the first year number of filled grains per ear at 40 and 80 kg N/ha were at par. In the
second year 40 kg and the control plot and 80 and 120 kg N/ha were at par. Potassium particularly increased the number of filled grains per panicle in rice and per ear in wheat over the control. Higher number of sterile grains/panicle was found with the increasing levels of nitrogen during both the years. On the other hand, application of phosphorus and potassium levels reduced the sterility. Weight of thousand grains of rice and wheat increased with increasing levels of nitrogen and phosphorus. In case of rice at the control and 40 kg N/ha it was higher in the first year, while at 80 and 120 kg N/ha it was found higher in the second year. Significant difference between the control and 120 kg N/ha was found in the second year of wheat crop. Application of 40 and 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded higher test weight in the second year in rice crop. Potassium had no effect on thousand grain weight in either of the crops.

Nitrogen application consistently and significantly increased the yield of grains over its preceding nitrogen level upto 80 kg N/ha in rice and upto 120 kg N/ha in wheat. In case of rice, application of 40 and 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded significant superiority over the control, but both were found at par. While in wheat crop significant differences were observed only between the control and 80 kg P<sub>2</sub>O<sub>5</sub>/ha. Application of 40 kg P<sub>2</sub>O<sub>5</sub>/ha recorded significant increase in wheat grain yield only during the second year. But effect of potassium alongwith lower and medium level of nitrogen (N<sub>40</sub>P<sub>0</sub>K<sub>40</sub> and N<sub>80</sub>P<sub>0</sub>K<sub>40</sub>) were found quite promising during both the years in rice crop. In case of wheat also addition of potassium alongwith 80 and 120 kg N/ha (i.e., N<sub>80</sub>P<sub>80</sub>K<sub>40</sub>, N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> and N<sub>120</sub>P<sub>80</sub>K<sub>40</sub>) recorded higher grain yield over nitrogen alone. Each increment of nitrogen recorded significant increase in straw yield of rice and wheat during both the years. In case of rice, phosphorus levels gave higher straw yield with their increasing levels, but none of them was found significant. On the other hand 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded significantly higher straw yield over the control in case of wheat.
straw. Differences between 40 and 80 kg P$_{2}$O$_{5}$/ha were not significant. Increase in straw yields due to potassium application was rather marginal.

Input -output relationship between levels of nitrogen and yield of rice and wheat grain showed that the response followed the law of diminishing return. Maximum rate of nitrogen for rice was calculated to be 113.20 ,112.40 and 115.80 kg N/ha and most profitable rate 88.40, 84.0 and 78.0 kg N/ha, respectively during the first and the second year as well as with the mean of two years. In case of wheat crop, maximum rate of nitrogen was found to be 140 kg N/ha and most profitable rate 123.60 kg N/ha during the second year. In case first year both were found more than the highest level of nitrogen tried, i.e., 120 kg N/ha.

The magnitude of grain yield response increased with increasing levels of nitrogen in rice ad wheat crop during both the years of experimentation. In case of rice, the response increased upto 80 kg P$_{2}$O$_{5}$/ha in the first year and only upto 40 kg P$_{2}$O$_{5}$/ha during the second year. In wheat crop, response increased with increasing levels of phosphorus upto 80 kg P$_{2}$O$_{5}$/ha during both the years. Response over immediately previous nitrogen and phosphorus levels showed decreasing trend with increasing levels of nitrogen and phosphorus . Response at 40 kg K$_{2}$O/ha over the control was obtained only during the second year of wheat crop. Rice crop in the first year recorded very small increase in grain yield due to potassium fertilization.

Net profit and additional profit over the control increased with increasing levels of nitrogen and the highest profits were obtained at 120 Kg N/ha in both the crops. But the application of 120 kg N/ha over 80 kg nitrogen marginally increased the profit in rice. While in wheat crop it was 120 kg nitrogen which recorded quite higher profit over 80 kg N/ha. In case of phosphate fertilization, profit were mostly in favour of 40 kg P$_{2}$O$_{5}$/ha in case of rice crop and
80 kg P₂O₅/ha in wheat. The maximum profit was recorded with 80 kg P₂O₅/ha. Application of 40 kg K₂O gave small profit in case of wheat crop only.

Response of both nitrogen and phosphorus fertilizers in producing grain per kg of nutrient applied was found to be maximum at their lower levels and as the level of nitrogen and phosphorus increased their response of producing grain per kg of nutrient applied decreased. Response due to potassium fertilization was negligible in rice, but was apparent in wheat. Nitrogen content was found increasing with increasing levels of nitrogen and phosphorus. On the other hand, potassium had only small effect in rice and wheat during both the years. Uptake of nitrogen increased with increasing levels of nitrogen, phosphorus and potassium due to increase in biological yield. Phosphorus content in rice and wheat plant was found to be the maximum in the control plots and as the level of nitrogen increased phosphorus content decreased. but uptake data showed increasing trend with increasing levels of nitrogen. Phosphorus levels (40 and 80 Kg P₂O₅/ha) improved phosphorus content of rice and wheat grain and straw. The uptake of phosphorus was found increasing with increase in the levels of phosphorus fertilizer. The application of potassium also improved the content of phosphorus. Different levels of nitrogen, phosphorus and potassium caused appreciable improvement in potassium content of rice and wheat plants. Such an effect was more pronounced due to potassium application. Higher uptake of potassium was recorded at higher levels of nitrogen, phosphorus and potassium in comparison to their lower levels. There was greater depletion of total nitrogen in soil with increasing levels of nitrogen fertilizers during both the years. An increasing loss of available phosphorus was also experienced at all the levels of phosphorus applied excluding the control, where there was a positive gain. Balance of available potassium in soil was found positive after each crop cycle, which showed a decreasing trend in the second year.
The following broad conclusions may be drawn on the basis of the results of the present investigation.

1. Growth and yield attributes increased with increasing levels of nitrogen and phosphorus. Potassium had very minor effect, however, it increased the number of filled grains and thousand grain weight appreciably.

2. Grain yield increased with increasing levels of nitrogen and 80 kg N/ha in rice and 120 kg N/ha in wheat increased the yield significantly. Similarly 40 kg P$_2$O$_5$/ha in rice and 80 kg P$_2$O$_5$/ha in wheat crop gave higher yield over the other levels of phosphorus. Significant effect of potassium was found only in wheat crop during the second year.

   Effect of potassium was found quite promising at 40 kg N/ha (N$_{40}$P$_{0}$K$_{40}$) and 80 kg N/ha (N$_{80}$P$_{0}$K$_{40}$) in rice. In case of wheat also at 80 and 120 kg N/ha with or without phosphorus (i.e. N$_{80}$P$_{80}$K$_{40}$, N$_{120}$P$_{0}$K$_{40}$ and N$_{120}$P$_{80}$K$_{40}$) increase the grain yield quite remarkably.

3. Maximum rate of nitrogen for rice was calculated to be 113.20 kg N/ha and 112.40 Kg N/ha in the first and the second year, respectively and the most profitable rate was 88.40 kg N/ha in the first year and 84 kg N/ha in the second year. On the other hand, the maximum rate of nitrogen was 140 kg/ha and most profitable rate was 123.60 kg N/ha in the second year in wheat crop. During the first year both were found quite high.

4. Magnitude of grain yield response increased with increasing levels of nitrogen. In case of phosphorus, response increased upto 80 kg P$_2$O$_5$/ha in the first year, but upto 40 kg P$_2$O$_5$/ha in the second year. Wheat crop responded upto 80 kg P$_2$O$_5$/ha in both the years. The response of nitrogen and phosphorus over its immediate previous level decreased with increasing levels of nitrogen and phosphorus. Response of potassium was noticed only during the second year of wheat crop.
(5) Net profit and additional profit were found favourable only upto 80 kg nitrogen and 40 kg phosphorus per hectare in rice. While in the wheat they were found profitable at 120 kg nitrogen and 80 kg phosphorus per hectare. No appreciable gain due to potassium application was noticed in rice, although it gave minor profit in wheat.

(6) Higher response of nitrogen, phosphorus and potassium in producing grain per kg of nutrient applied was found at their lower level of application and as their level increased, response decreased.

(7) Higher content of nitrogen, phosphorus and potassium was found with increasing levels of nitrogen, phosphorus and potassium, respectively. Their uptake increased with increasing levels of nitrogen, phosphorus and potassium fertilizers.

(8) Total nitrogen decreased in soil with each crop cycle. Reduction was sharp at the higher levels of nitrogen fertilization. Except the control plot, available phosphorus decreased in all the phosphorus treated plots. Potassium had positive balance but it showed a decreasing trend after each crop cycle.

**Recommendations**

Keeping in view all the above mentioned facts 40 kg N and 40 kg K₂O/ha was found economical for rice and 120 kg N, 80 kg P₂O₅ and 40 kg K₂O/ha for wheat. Application of phosphorus in rice can not be recommended keeping in view the fact that wheat crop can not utilize all the added phosphorus and leaves phosphorus in the soil which will be available for coming rice crop. Rice crop is also known to be the best utilizer of native phosphorus in comparison to wheat and can exploit phosphorus fractions of soil very easily. However, soil test for available phosphorus after each crop cycle (rice-wheat) will be essential and if soil shows any sign of reduction in status of available phosphorus,
application of phosphorus 40 Kg P₂O₅/ha along with N₁₂₀K₄₀ will become essential for higher yield and sustaining soil productivity.

The biomass of weed in g/m² with respect to various water treatments was estimated during the growing period and results indicate that the biomass of whole plant did not show much difference during early stages of growth in every water condition. Maximum increase in biomass was found in between the period from 75 to 90 days in each case. As evident from the result the biomass of whole plant varies at different growth stages in each water treatment. The minimum biomass of whole plant was found to be 12.64, 12.58, and 12.88 g/m² at seedling stage for the conditions biweekly, weekly, fortnightly and excessive watering, respectively. The maximum biomass of whole plant was found to be 388.40, 340.28, 320.24, 316.45 g/m² for the conditions fortnightly, weekly, biweekly and excessive watering, respectively. Therefore maximum biomass of whole plant was found in case of fortnightly watering followed by weekly, biweekly and excessive watering. The net primary productivity increases with the age up to 90 days in case of fortnightly and excessive watering and upto 105 days in case of biweekly and weekly watering, after attaining peak value the productivity declines in each case. The maximum net primary productivity was found to be 52.5, 40.2, 38.2 and 29.0 g/m²/day for the treatment biweekly, weekly, fortnightly and excessive watering respectively. The maximum net primary productivity was found in case of biweekly followed by weekly, fortnightly and excessive watering.

The relative growth rate (mg/g/day) i.e. daily rate of gain in dry weight (RGR) decreases continuously as the age of plant increases. The maximum value of RGR was found to be 189.3, 166.0, 134.0 and 132.0 mg/g/day for the treatment biweekly, weekly, fortnightly and excessive watering respectively. The net assimilation rate (g/m²/day) i.e. net diurnal efficiency of assimilation per unit of
assimilation surface (NAR) decreases continuously with the increasing age. The maximum value of NAR was found to be ranging from 10.5 to 14.2 g/m²/day and the minimum value was ranging from 5.3 to 6.3 g/m²/day in each case. Effect of various water treatments on leaf area ratio (LAR in terms of cm²/g) decreases continuously with the increasing age. The maximum value of LAR was found to be ranging from 97.1 to 144.4 cm²/g in each case.