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# System Productivity, Economics and Nutrient Use Efficiency in Maize (*Zea mays* L.) - Chickpea (*Cicer arietinum* L.) Cropping Sequence

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ABSTRACT

Adoption of cereal-legume sequence cropping is imperative to achieve sustainability, nutritional security and to improve profitability. In this regard field experiment was conducted for two consecutive years at Mudhol, Karnataka with the intension of optimization of maize-chickpea cropping system for higher productivity and profitability. During *kharif*, maize crop with three maize hybrids ('NK 6240', 'Super 900 M' and 'Arjun'), 2 plant populations (1,11,111 and 83,333 plants/ha) and 5 fertility levels $N_{(150)}P_2O_{5(65)}K_2O_{(65)}$, $N_{(187)}P_2O_{5(81)}K_2O_{(81)}$, $N_{(225)}P_2O_{5(97)}K_2O_{(97)}$, $N_{(262)}P_2O_{5(114)}K_2O_{(114)}$ and $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$kg/ha were tested. While, in succeeding *rabi*, a residual chickpea was taken up in the same plot under split-split plot concept with three replications. Significantly, higher maize equivalent yield (MEY) (12.30 t/ha), system production efficiency (SPE) (51.59 kg/ha/day) and system net returns (SNR) (Rs.1.07 lakh/ha) of cropping system was registered with'NK 6240'. Between plant population, maize sown with 111,111 plants/ha gave significantly higher MEY (12.28 t/ha), system production efficiency (50.42 kg/ha/day), system net returns (Rs.1.05 lakh/ha) than 83,333 plants/ha on account of higher grain and stover yields. Similar trend of significant excellence in MEY (13.22 t/ha), SPE (56.14 kg/ha/day), SNR (Rs.1.18 lakh/ha) of maize-chickpea cropping sequence was observed with application of $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$kg/ha. The agronomic efficiency (AE) of applied fertilizer increased with increase in fertilizer levels whereas partial factor productivity and nutrient response ratio exhibited inverse trend with increased fertilizer levels.

*Keyword*: Economics, Efficiency, Chickpea, Cropping-system, Maize, Productivity, Uptake

MAIZE is an important food and feed crop which ranks third after wheat and rice in India and first in the world. Because of its expanded use in the agro-industries, it is recognized as a leading commercial crop of great agro-economic value (Hasim *et al*., 2015). In India maize is being cultivated in about 8.71 million ha, with total annual production of 22.3 million tonnes of grain giving an average yield of 2.55 tonnes per hectare (Anonymous, 2018) however, is tremendously lower than other maize-growing countries of the world (5.16 t/ ha). Yield gap in maize is mainly due to inadequate and imbalanced fertilization and lack of distinct fertilizer recommendations for high-yielding hybrids of maize (Kumar *et al*., 2015).Maize-chickpea is a popular and profitable cropping system in *Vertisols* of northern Karnataka (Hiremath *et al*., 2016) as it secures monetary as well as food and nutritional needs of the growers, therefore farmers are habituated cultivation of *kharif* maize followed by chickpea in succeeding *rabi* season. However, in recent days, productivity of maize based cropping systems in rainfed agro-ecosystem is declining drastically due to sowing of low yielding genotypes besides practicing unscientific agro-techniques especially with planting density and nutrient management (Kumar *et al*., 2015). Further, maize being the non-tillering cereal crop, any amount of reduced population would not compensate final yield by improvement in individual reproductive units (cobs) as pointed out by Kumar and Girijesh (2015). Maize being the member of C4 family, respond well to applied water and nutrients. The study conducted by Kumar *et al*. (2015) indicated that, there is a great disparity in nutrient mining by maize and is greatly influenced by nature and duration of genotype, planting density and availability of nutrients. In the context of intensive cropping, farmers usually cultivate single cross maize hybrids bread and released by private companies which are locally available in seed market with higher seed rate and elevated rates of fertilizer application (Kumar *et al*., 2015). In such situation, nutrient built-up is bound to happen. Nutrient build-up in cropping system over the period of time was earlier reported by Hiremath and Hosamani (2015) and Panwar *et al*. (2019). Harnessing the potentiality of residual nutrient under sequence cropping not only optimize fertilizer economy but also helps in avoiding environmental risk due to nutrient leaching and eutrophication of water bodies as suggested by Maaz and Pan (2017) and Torma *et al*. (2017). Chickpea is the popular crop cultivated in *rabi* season to take best possible benefits of residual moisture and nutrients under deep black soil condition in maize based cropping sequence in the study area. An unfertilized chick pea crop was sown and studied for its growth and yield attributing traits under fixed plot with minimum tillage concept to know the residual effects of preceding maize on succeeding chickpea.

Knowledge on effects of agro techniques of preceding maize and their residual effects on succeeding chickpea in maize-chickpea cropping sequence is essential to unlock the potentiality of cropping system. Hence, this study aims to devise a biologically feasible, economically viable and resource use efficient replicable model maize chickpea cropping system.

## Material and Methods

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at Mudhol, Karnataka to study the effects of single-cross hybrids, plant population and level of fertilization on growth and yield attributes, yield, nutrient uptake and economics of maize and their residual effect on succeeding chickpea under maize-chickpea cropping sequence. The soil of the experimental site was deep black, alkaline, low in organic carbon and available nitrogen (237 kg/ha), medium in available phosphorus (23 kg / ha) and high in available potassium (427 kg / ha). The experiment was laid out in split-split plot design and was replicated thrice. Three hybrids ($H_1$, 'NK 6240', '$H_2$', 'Super 900 M' and '$H_3$', 'Arjun'), 2 populations ($P_1$, 111, 111 and $P_2$, 83, 333 plants/ha) and 5 fertility levels [$F_1$, $N_{(150)}P_2O_{5(65)}K_2O_{(65)}$, $F_2$, $N_{(187)}P_2O_{5(81)}K_2O_{(81)}$, $F_3$, $N_{(225)}P_2O_{5(97)}K_2O_{(97)}$, $F_4$, $N_{(262)}P_2O_{5(114)}K_2O_{(114)}$ and $F_5$, $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$] were assigned to main plots, subplots and sub-subplots, respectively.

Well decomposed farmyard manure @ 10 tonnes and 25 kg each of $ZnSO_4$ and $FeSO_4$ / ha were applied uniformly and seeds were treated with phosphorus-solibilizing bacteria and *Azospirillum* each @ 750 g / ha. As per the treatments, seed rows were maintained at 45 cm and 60 cm to accommodate 111, 111 and 83,333 plants/ha in subplots. Interrow spacing of 20 cm was maintained for both the populations. Basal dose of nitrogen (15 % of RDN), phosphorus (100 % RD $P_2O_5$), potassium (RD $K_2O$) and micronutrients were applied at the time of sowing and remaining nitrogen was applied in 4 splits at 20, 35, 50 and 65 days after sowing. After harvest of the maize crop, soil from the experimental plots were analyzed for available nitrogen, phosphorous and potassium by adopting standard methodology before sowing *rabi*crop. During *rabi* season, an unfertilized chick pea crop was sown and studied for its growth and yield attributing traits under fixed plot with minimum tillage concept to know the residual effect of preceding maize on growth and yield of succeeding chickpea. Observations on growth, yield attributes, grain/seed and stover/haulm yields were recorded as per the standard procedure. Agronomic efficiency, partial factor productivity and nutrient response ratios were calculated as per methodology suggested Dobermann (2007).

$$AE = \frac{\text{Grain yield in fertilized plot (kg / ha)- grain yield with RDF (kg / ha)}}{\text{Quantity of nutrients applied (kg / ha)}}$$

$$PFP = \frac{\text{Grain yield (kg / ha)}}{\text{Nutrients applied (kg / ha)}}$$

$$NRR = \frac{\text{Grain yield in suceeding level (kg / ha)- grain yield preceding level (kg / ha)}}{\text{Quantity of nutrients applied (kg / ha)}}$$

Maize equivalent yield (MEY), system production efficiency (SPE) and system net returns (SNR) were calculated to know the productivity and economics of the cropping system. The cost of cultivation, gross and net returns and system net returns of both the crops were calculated on the basis of prevailing market price of different inputs and outputs. Data were statistically analyzed as suggested by Gomez and Gomez (1984).

$$\text{MEY} = \text{Yield of maize} + \text{Yield of chickpea} \times \frac{\text{Market price of chickpea (Rs./t)}}{\text{Market price of maize (Rs./t)}}$$

$$\text{SPE (kg / ha / day} = \frac{\text{Maize crop equivalent yield (kg / ha)}}{\text{Duration of preceding crop + duration of succeding crop (day)}}$$

$$\text{SNR (Rs.ha)} = \text{Net returns of maize + net returns of chickpea}$$

## Results and Discussion

### Performance of Maize

Hybrid 'NK 6240' and 'Super 900 M' gave significantly higher grain and stover yields than hybrid 'Arjun' (Table 2). Higher yield registered with former hybrids were traced back to higher yield attributes (cob length, cob girth, grain weight/plant and 1,000-grain weight) of these hybrids and were significantly higher than 'Arjun'. Significant improvement in yield attributing traits were again traced back to excellence in growth attributing traits associated with 'NK 6240' and 'Super 900 M' (Table 1). Increase in plant population per unit area from 83,333 to 1,11,111 plants/ ha increased the grain yield from 8.61 to 9.80 t/ha. Despite lower yield attributes in higher plant population (grain weight/plant and 1,000-grain weight), higher grain yield under higher plant population may be attributed to greater numbers of harvestable cobs per unit area. Better development of yield attributes at lower plant density could not compensate the loss in grain yield due to less number of harvestable cobs/ unit area (Bisht *et al.,* 2013) and was obvious because in non-tillering cereals like maize, the reduced plant population/unit area could not compensate to the final yield though the yield/plant harvested was little lower in higher plant population. Among the fertility levels, application of $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$ kg/ha recorded significantly higher grain and stover yields compared to the three lower levels *viz.,* $N_{(150)}P_2O_{5(65)}K_2O_{(65)}$, $N_{(187)}P_2O_{5(81)}K_2O_{(81)}$ and $N_{(225)}P_2O_{5(97)}K_2O_{(97)}$ and was at par with $N_{(262)}P_2O_{5(114)}K_2O_{(114)}$ kg/ha (Table 2). However, these fertility levels were at par with each other, a similar trend was observed for yield attributes such as cob length, cob girth, hundred seed weight and grain weight per plant. The increase in yield at higher fertility level could be due to increased sink capacity. The grain yield of maize mainly depends on the growth and yield attributes. The positive and significant improvement in crop-growth rate and net assimilation rate attributed to higher leaf-area index as well as total dry-matter production during crop-growth and development might have increased yield attributes resulting in enhanced grain yield. A very similar results was obtained in the present study.

### Performance of Chickpea

In this study, enhanced yield of chickpea was the index of excellence in growth and yield attributes. Significantly higher number of pods per plant (33.30) and seed weight per plant (18.68 g) were obtained in the plots where preceding maize was occupied with maize hybrid Arjun. Significant improvement in the yield attributing parameters of chickpea with former treatment reflected in significantly higher seed and haulm yield of chickpea (Table 4). Significant and positive co-relation between yield attributes and yield in chickpea was earlier reported by Hiremath and Hosamani (2015); Kumar and Hiremath (2015). Further, significant improvement in yield attributes of chickpea was noticed with the plots where preceding maize was cultivated at 83, 333 plants per hectare (Table 4). Significant excellence of growth, yield attributes and yields of chickpea in former treatment could be due higher amount of available nitrogen, phosphorous and potassium remained in the plots where a lower population of maize (83, 333 plants per hectare was maintained (Table 4). Similarly, plots

TABLE 1

Growth and yield attributes of maize in maize – chickpea cropping sequence (Pooled data of 2 years)

| Treatment | LAI at 90 DAS | Total dry matter production (g/plant) | CGR at 60-90 DAS | NAR at 60-90 DAS | Cob length (cm) | Cob girth (cm) | 100 seed weight (g) | Grain weight/ plant (g) |
|---|---|---|---|---|---|---|---|---|
| *Maize hybrids (H)* | | | | | | | | |
| $H_1$-NK-6240 | 5.17 | 290.8 | 53.32 | 5.3 | 17.71 | 15.87 | 42.37 | 174.67 |
| $H_2$-Super 900-M | 5.20 | 275.3 | 50.63 | 5.2 | 18.74 | 17.23 | 37.32 | 163.92 |
| $H_3$-Arjun | 4.08 | 201.8 | 35.44 | 3.6 | 16.21 | 13.40 | 33.33 | 90.90 |
| S.Em.± | 0.10 | 2.3 | 1.60 | 0.23 | 0.40 | 0.39 | 0.09 | 3.53 |
| LSD (P=0.05) | 0.37 | 9.1 | 4.80 | 0.70 | 1.236 | 1.2051 | 0.2781 | 10.9077 |
| *Plant population ha$^{-1}$ (P)* | | | | | | | | |
| P1- 1, 11, 111 | 5.26 | 240.0 | 52.44 | 4.7 | 17.12 | 15.39 | 37.46 | 136.65 |
| P2- 83, 333 | 4.38 | 271.9 | 40.48 | 4.7 | 17.98 | 15.61 | 37.88 | 149.69 |
| S.Em.± | 0.06 | 3.1 | 0.67 | 0.12 | 0.27 | 0.28 | 0.03 | 2.70 |
| LSD (P=0.05) | 0.21 | 10.9 | 2.10 | 0.40 | 0.84 | 0.87 | 0.09 | 8.37 |
| *Fertility levels kg ha$^{-1}$ (F)* | | | | | | | | |
| $F_1$-$N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ | 4.02 | 218.9 | 41.51 | 4.1 | 15.58 | 13.98 | 37.10 | 101.83 |
| $F_2$- $N_{(187)}$ $P_2O_{5(81)}K_2O_{(81)}$ | 4.41 | 245.1 | 44.88 | 4.6 | 16.43 | 14.74 | 37.37 | 121.21 |
| $F_3$- $N_{(225)}$ $P_2O_{5(97)}K_2O_{(97)}$ | 4.81 | 258.8 | 46.73 | 4.7 | 17.65 | 15.51 | 3.74 | 150.27 |
| $F_4$- $N_{(262)}$ $P_2O_{5(114)}K_2O_{(114)}$ | 5.30 | 272.1 | 49.30 | 4.9 | 18.77 | 16.35 | 37.99 | 168.05 |
| $F_5$- $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$ | 5.54 | 284.9 | 49.89 | 5.2 | 19.34 | 16.94 | 38.16 | 174.47 |
| S.Em.± | 0.07 | 5.4 | 1.03 | 0.15 | 0.22 | 0.25 | 0.07 | 2.23 |
| LSD (P=0.05) | 0.21 | 15.5 | 3.13 | 0.50 | 0.68 | 0.77 | 0.22 | 6.89 |

TABLE 2

Yield, economics, agronomic efficiency, partial factor productivity, nutrient response ratio and nutrient uptake by maize in maize – chickpea cropping sequence (Pooled data of 2 years)

| Treatment | Grain yield of maize (t/ha) | Stover yield of maize(t/ha) | Partial factor Productivity (kg kg$^{-1}$) | Agronomic Efficiency (kg kg$^{-1}$) | Nutrient Response Ratio (kg kg$^{-1}$) | Net returns (x $10^3$Rs./ha) | BC ratio | Crop nutrient uptake (Above ground portion) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Nitrogen (kg/ha) | Phosphorous (kg/ha) | Potassium (kg/ha) |
| *Maize hybrids (H)* | | | | | | | | | | |
| $H_1$-NK-6240 | 10.14 | 14.38 | 24.64 | 4.12 | 1.51 | 87.56 | 2.68 | 290.4 | 49.0 | 112.7 |
| $H_2$-Super 900-M | 9.89 | 14.33 | 24.14 | 4.16 | 1.49 | 81.86 | 2.49 | 281.1 | 46.9 | 110.8 |
| $H_3$-Arjun | 7.59 | 11.84 | 18.09 | 3.43 | 1.44 | 61.09 | 2.38 | 220.1 | 34.9 | 96.7 |
| S. Em.± | 0.16 | 0.30 | 0.44 | - | - | 2.23 | 0.05 | 3.3 | 0.8 | 2.4 |
| LSD (P=0.05) | 0.49 | 0.92 | 1.36 | - | - | 8.76 | 0.21 | 10.23 | 2.48 | 7.44 |
| *Plant population ha$^{-1}$ (P)* | | | | | | | | | | |
| P1- 1, 11, 111 | 9.80 | 14.68 | 23.79 | 3.55 | 1.38 | 48.56 | 2.65 | 282.5 | 51.2 | 131.5 |
| P2- 83, 333 | 8.61 | 12.36 | 20.79 | 4.26 | 1.58 | 69.11 | 2.38 | 245.2 | 36.0 | 81.9 |
| S. Em.± | 0.15 | 0.15 | 0.53 | - | - | 2.01 | 0.04 | 4.0 | 0.9 | 2.6 |
| LSD (P=0.05) | 0.47 | 0.47 | 1.60 | - | - | 6.96 | 0.14 | 12.40 | 2.79 | 8.06 |
| *Fertility levels kg ha$^{-1}$ (F)* | | | | | | | | | | |
| $F_1$-$N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ | 7.38 | 12.57 | 26.36 | - | - | 57.51 | 2.27 | 205.1 | 30.8 | 73.5 |
| $F_2$- $N_{(187)}$ $P_2O_{5(81)}K_2O_{(81)}$ | 8.43 | 13.12 | 24.16 | 3.02 | 3.02 | 69.01 | 2.44 | 248.9 | 37.9 | 84.7 |
| $F_3$- $N_{(225)}$ $P_2O_{5(97)}K_2O_{(97)}$ | 9.69 | 13.81 | 23.06 | 5.49 | 2.99 | 83.35 | 2.65 | 265.9 | 43.7 | 108.0 |
| $F_4$- $N_{(262)}$ $P_2O_{5(114)}K_2O_{(114)}$ | 10.12 | 14.02 | 19.77 | 5.60 | 0.89 | 86.44 | 2.64 | 290.1 | 50.7 | 127.8 |
| $F_5$- $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$ | 10.42 | 14.08 | 18.08 | 5.42 | 0.52 | 84.86 | 2.59 | 309.3 | 54.9 | 139.6 |
| S. Em.± | 0.22 | 0.33 | 0.58 | - | - | 2.94 | 0.06 | 5.7 | 0.8 | 2.4 |
| LSD (P=0.05) | 0.683 | 1.021 | 1.762 | - | - | 8.36 | 0.17 | 17.67 | 2.48 | 7.44 |

TABLE 3

Available nutrient status of the soil after harvest of maize in maize-chickpea cropping sequence (Pooled data of 2 years)

| Treatments | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|
| | Nitrogen (kg/ha) | Phosphorus (kg/ha) | Potassium (kg/ha) | Nitrogen (kg/ha) | Phosphorus (kg/ha) | Potassium (kg/ha) |
| *Maize hybrids (H)* | | | | | | |
| $H_1$-NK-6240 | 219.4 | 52.5 | 429.4 | 205.1 | 60.8 | 449.8 |
| $H_2$-Super 900-M | 222.8 | 54.1 | 427.6 | 212.2 | 61.9 | 457.4 |
| $H_3$-Arjun | 252.2 | 63.8 | 446.6 | 284.4 | 70.5 | 477.6 |
| S. Em.± | 3.5 | 1.1 | 25.2 | 3.4 | 4.2 | 23.0 |
| LSD (P=0.05) | 11.5 | 3.4 | 80.1 | 11.1 | 13.5 | 76.2 |
| *Plant population ha$^{-1}$ (P)* | | | | | | |
| P1- 1, 11, 111 | 225.2 | 51.3 | 421.1 | 225.7 | 59.4 | 448.4 |
| P2- 83, 333 | 237.8 | 62.3 | 448.1 | 242.1 | 69.4 | 478.8 |
| S. Em.± | 2.7 | 0.9 | 6.2 | 1.8 | 2.5 | 6.1 |
| LSD (P=0.05) | 9.1 | 3.4 | 29.6 | 6.01 | 9.4 | 21.3 |
| *Fertility levels kg ha$^{-1}$ (F)* | | | | | | |
| $F_1$-$N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ | 200.8 | 43.1 | 382.0 | 205.6 | 49.4 | 408.6 |
| $F_2$- $N_{(187)}$ $P_2O_{5(81)}K_2O_{(81)}$ | 218.5 | 49.0 | 407.9 | 220.1 | 56.1 | 436.3 |
| $F_3$- $N_{(225)}$ $P_2O_{5(97)}K_2O_{(97)}$ | 233.3 | 57.0 | 443.5 | 236.1 | 63.0 | 471.0 |
| $F_4$- $N_{(262)}$ $P_2O_{5(114)}K_2O_{(114)}$ | 246.2 | 63.3 | 460.3 | 258.3 | 71.3 | 485.1 |
| $F_5$- $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$ | 258.7 | 71.7 | 479.1 | 259.3 | 82.2 | 507.1 |
| S. Em.± | 4.31 | 1.40 | 10.90 | 3.41 | 1.50 | 11.41 |
| LSD (P=0.05) | 13.52 | 5.54 | 33.61 | 12.14 | 5.23 | 36.31 |

where preceding maize fertilized with $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$ kg per hectare recorded significantly higher number of pods per plant (38.87), seed weight per plant (20.78 g), seed and haulm yields of chickpea over rest of the fertility levels (Table 4). It could be due to higher levels of available nutrient in the soil after harvest of preceding maize that might nourished the residual chickpea than rest of the fertility levels (Table 3). Yield improvement in residual crop under sequence cropping where preceding crop fertilized with elevated fertility levels was earlier reported by Kumar and Hiremath (2015).

**Nutrient use Efficiency**

Among the maize hybrids, NK-6240 recorded higher AE (4.12 kg/kg), PFP (24.64 kg/kg) and NRR (1.51 kg/kg) than Super 900-M and Arjun (Table 2). Higher plant population recorded higher AE (4.26 kg/ka), (23.79 kg/kg) and NRR (1.58 kg/kg) than lower plant population (Table 2). Among the fertility levels, maize fertilized with $N_{(262)}P_2O_{5(114)}K_2O_{(114)}$ kg/ha recorded higher AE (5.60 kg/kg) and was remain comparable with that of $N_{(225)}P_2O_{5(97)}K_2O_{(97)}$ kg/ha (5.49) than their higher and lower doses whereas partial factor productivity and nutrient response ratio decreased

TABLE 4

Yield attributes, yield, economics and nutrient uptake by chickpea in maize-chickpea cropping sequence (Pooled data of 2 years)

| Treatment | Number of pods/plant | Seed weight/ plant(g) | Seed yield of chickpea (q ha$^{-1}$) | Haulm yield of chickpea (q ha$^{-1}$) | Net returns (x 10$^3$Rs./ha) | BC ratio | Crop nutrient uptake (Above ground portion) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Nitrogen (kg/ha) | Phosphorus (kg/ha) | Potassium (kg/ha) |
| *Maize hybrids (H)* | | | | | | | | | |
| $H_1$-NK-6240 | 25.82 | 15.08 | 6.79 | 14.00 | 19.3 | 2.85 | 23.6 | 12.1 | 20.9 |
| $H_2$-Super 900-M | 29.06 | 16.42 | 6.99 | 14.64 | 20.2 | 2.94 | 26.8 | 13.8 | 23.5 |
| $H_3$-Arjun | 33.30 | 18.68 | 8.50 | 16.19 | 26.3 | 3.49 | 33.2 | 17.1 | 29.3 |
| S. Em.± | 0.68 | 0.23 | 0.30 | 0.42 | 1.23 | 0.01 | 1.3 | 0.6 | 1.3 |
| LSD (P=0.05) | 2.1012 | 0.7107 | 0.927 | 1.2978 | 3.75 | 0.03 | 4.03 | 1.86 | 4.03 |
| *Plant population ha$^{-1}$ (P)* | | | | | | | | | |
| P1- 1, 11, 111 | 28.31 | 16.10 | 6.96 | 14.55 | 20.02 | 3.06 | 26.6 | 13.7 | 23.6 |
| P2- 83, 333 | 30.48 | 17.35 | 7.90 | 15.34 | 23.92 | 3.13 | 29.0 | 14.9 | 25.5 |
| S. Em.± | 1.00 | 0.39 | 0.25 | 0.19 | 1.05 | 0.05 | 0.8 | 0.3 | 0.6 |
| LSD (P=0.05) | 3.10 | 1.21 | 0.78 | 0.59 | 3.15 | 0.16 | 2.48 | 0.93 | 1.86 |
| *Fertility levels kg ha$^{-1}$ (F)* | | | | | | | | | |
| $F_1$-$N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ | 18.10 | 11.95 | 5.49 | 13.31 | 14.13 | 2.26 | 21.4 | 11.0 | 19.0 |
| $F_2$- $N_{(187)}$ $P_2O_{5(81)}K_2O_{(81)}$ | 23.90 | 14.15 | 6.48 | 13.82 | 18.14 | 2.73 | 24.3 | 12.5 | 21.5 |
| $F_3$- $N_{(225)}$ $P_2O_{5(97)}K_2O_{(97)}$ | 30.92 | 17.17 | 7.36 | 14.95 | 21.71 | 3.17 | 28.4 | 14.6 | 25.1 |
| $F_4$- $N_{(262)}$ $P_2O_{5(114)}K_2O_{(114)}$ | 35.16 | 19.57 | 8.46 | 15.99 | 26.13 | 3.46 | 30.9 | 15.9 | 27.3 |
| $F_5$- $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$ | 38.87 | 20.78 | 9.34 | 16.63 | 29.75 | 3.86 | 34.2 | 17.5 | 29.9 |
| S. Em.± | 0.96 | 0.39 | 0.16 | 0.25 | 6.97 | 0.05 | 0.6 | 0.3 | 0.6 |
| LSD (P=0.05) | 2.97 | 1.21 | 0.49 | 0.77 | 21.0 | 0.16 | 1.86 | 0.93 | 1.86 |

gradually as the fertility levels increased. Higher PFP (26.36 kg kg$^{-1}$) was obtained with crop fertilized with $N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ kg/ha and the lowest was with $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$kg/ha (18.08) fertility level (Table 2).

**System Productivity**

Equivalent yield is an important indicator used to asses productivity of cropping systems especially when produces are dissimilar. In this study, significantly higher maize equivalent yield (MEY) was recorded for NK-6240 (12.30 t/ha) and Super 900-M (12.12 t/ha) than Arjun followed by unfertilized residual chickpea. Significantly higher MEY was ascribed to significantly higher grain yield of maize in maize-chickpea cropping system. Similar results were earlier reported by (Hiremath *et al.*, 2016) in maize-chickpea cropping system. The system production efficiency (SPE) was also higher with NK-6240 and Super 900-M hybrids (51.59 and 50.81 kg/ha/day, respectively). It could be due to significantly higher MEY when preceding maize hybrid was NK-6240 or Super 900-M than Arjun (Table 5). System profitability (system net returns) is the ultimate indicator that decides viability of cropping system. In this study, significantly higher system net return (SNR) was registered with NK-6240 (Rs.1.07 lakh/ha) or Super 900-M (Rs.1.02 lakh ha$^{-1}$) on account of higher grain yield of maize and market price for succeeding chickpea. Between the plant densities significantly higher MEY (33.45 t/ha), SPE (140.37 kg/ha/day) and SNR (Rs.1.05 lakh/ha) was recorded with maize

TABLE 5

Maize equivalent yield, system production efficiency and system net returns of maize - chickpea cropping sequence (Pooled data of 2 years)

| Treatment | Maize equivalent yield (t/ha) | System production Efficiency (kg/ha/day) | Net returns of maize (Rs/ha) | Net returns of chickpea (Rs/ha) | System net returns (Lakh Rs/ha) |
|---|---|---|---|---|---|
| *Maize hybrids (H)* | | | | | |
| $H_1$-NK-6240 | 12.30 | 51.59 | 87560 | 19305 | 1.07 |
| $H_2$-Super 900-M | 11.76 | 50.81 | 81856 | 20238 | 1.02 |
| $H_3$-Arjun | 10.77 | 43.25 | 61088 | 26388 | 0.87 |
| S. Em.± | 0.24 | 0.67 | 2231 | 123 | 0.02 |
| LSD (P=0.05) | 0.74 | 2.08 | 6916.10 | 381.30 | 0.06 |
| *Plant population ha$^{-1}$ (P)* | | | | | |
| P1- 1, 11, 111 | 12.28 | 50.42 | 84563 | 20026 | 1.05 |
| P2- 83, 333 | 10.95 | 46.67 | 69109 | 23928 | 0.93 |
| S. Em.± | 0.16 | 0.73 | 2011 | 1052 | 0.02 |
| LSD (P=0.05) | 0.50 | 2.26 | 6234.10 | 3261.20 | 0.07 |
| *Fertility levels kg ha$^{-1}$ (F)* | | | | | |
| $F_1$-$N_{(150)}P_2O_{5(65)}K_2O_{(65)}$ | 9.57 | 38.35 | 57514 | 14137 | 0.72 |
| $F_2$- $N_{(187)}$ $P_2O_{5(81)}K_2O_{(81)}$ | 10.76 | 44.06 | 69014 | 18140 | 0.87 |
| $F_3$- $N_{(225)}$ $P_2O_{5(97)}K_2O_{(97)}$ | 11.81 | 50.45 | 83347 | 21711 | 1.05 |
| $F_4$- $N_{(262)}$ $P_2O_{5(114)}K_2O_{(114)}$ | 12.71 | 53.45 | 86439 | 26139 | 1.13 |
| $F_5$- $N_{(300)}$ $P_2O_{5(130)}K_2O_{(130)}$ | 13.22 | 56.14 | 87859 | 29757 | 1.18 |
| S. Em.± | 0.16 | 0.97 | 2941 | 697 | 0.03 |
| LSD (P=0.05) | 0.50 | 3.01 | 9117.10 | 2160.70 | 0.10 |

cultivated at higher plant density (1,11,111 plants/ ha) followed by residual chickpea mainly due to higher grain yield of maize at higher plant population. Further, maize fertilized with $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$kg per hectare followed by residual chickpea in *rabi* recorded significantly higher MEY (13.39 t/ha), SPE (56.14 kg/ ha/day) and SNR (Rs.1.18 lakh/ha). Significant improvement in the yield of component crops (maize and chickpea) due to direct and residual effects at elevated fertility could be the probable reason for achieving significantly higher system productivity (Kumar *et al*., 2015).

**Nutrient Uptake**

Variation in nutrient uptake were recorded among the hybrids (Table 2); 'NK 6240' removed significantly higher amount of nitrogen, phosphorus and potassium and was closely followed by 'Super 900 M'. Single-cross maize hybrids produce more biomass/plant leading to higher biomass production may be the most relevant cause for higher nutrient uptake (Jat *et al*., 2012). Between the plant population, 111, 111 plants per hectare recorded higher nitrogen, phosphorus and potassium uptake and was obvious because of higher crop stand which produced higher biomass per hectare. Among the fertility levels, increased fertility levels enhanced the nutrient uptake of maize. $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$kg per recorded significantly higher uptake of nitrogen, phosphorus and potassium, but it was statistically on a par with $N_{(262)}P_2O_{5(114)}K_2O_{(114)}$ kg per hectare. Enhanced nutrient levels increased the availability of nutrients in the soil, which might have encouraged maize to consume nutrients luxuriously. These results are in close agreement with the findings of Jat *et al*. (2012) and Kumar *et al*. (2015).

Similarly, significantly higher nitrogen (33.2 kg/ha), phosphorous (17.1 kg/ha) and potassium (29.3 kg/ha) uptake by chickpea was observed when preceding maize hybrid was Arjun compared to NK-6240 and Super 900-M an account of significantly higher biomass production (Table 4). Between the plant population of preceding maize, maintenance of maize population at 83, 333 plants per hectare recorded significantly higher uptake of nitrogen (29.0 kg/ha), phosphorus (14.9 kg/ha) and potassium (25.5 kg/ha) over 1, 11, 111 plants per hectare. Among the fertility levels, chickpea cultivated in the plot where preceding maize fertilized with $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$ kg per hectare recorded significantly higher uptake of nitrogen (34.2 kg/ha), phosphorus (17.5 kg/ha) and potassium (29.9 kg/ha). Enhanced nutrient uptake in residual crops was due to higher dry matter production with succeeding chickpea. These results are in the lines of Kumar and Hiremath (2015).

Cultivation of maize using single cross hybrids maintaining a population density of 1, 11, 111 plants per hectare with the application of $N_{(300)}P_2O_{5(130)}K_2O_{(130)}$ kg per hectare in *kharif* followed by residual chickpea in *rabi* was found to be the most productive and profitable cropping system under *vertisols* of rainfed agro-ecosystem.

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