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Impact assessment of different irrigation and fertilizer levels on Mustard+Chickpea intercropping systems over sole cropping

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Abstract: Most appropriate quantity and time of irrigation and fertilization management are effective interventions to enhance productivity of mustard+chickpea cropping systems, for addressing food insecurity for an alarmingly growing population. Irrigation and fertility management plays a significant role in augmenting the production and productivity of mustard and chickpea intercropping systems. Therefore, in a two-year field experiment, the influence of different irrigation regimes and fertility gradients on performance chickpea and mustard in sole and intercropping systems were investigated. The results revealed that the cropping system did not influence mustard dry matter production but it did affect in chickpea. The application of two irrigations (I_3) and recommended dose of fertilizers (F_3) to these crops resulted in the highest dry matter accumulation. Similar was the influence in nutrient uptake and yield as well. The intercropping of chickpea and mustard in 4:1 ratio was significantly superior to sole crops of either chickpea or mustard in nutrient uptake and yield. Among the chickpea and mustard, cultivation of chickpea was better as compared to mustard in terms of higher returns. The application of two irrigations, one each during pre-flowering and pod formation stages of chickpea resulted in higher yield and chickpea equivalent yield. Over all, the application of recommended dose of fertilizers (20 N: 60 P: 20 S) to both the crops was found superior. The decrease in the intercropped mustard yield was to the tune of about 59% as compared to sole crop of mustard. Increasing the N application from 20 kg to 40 kg / ha did not enhance the yield level of any of these corps. The quantum of increase in seed yield due to F_2 and F_3 over F_1 were 10.6% and 16.6% in first year and 9.73% and 20.31% during second year, respectively.

Key words: Chickpea + mustard, Economics, Irrigation management, Nutrient management, Yield.

1. Introduction

Mustard (Brassica juncea L.) is one of the major edible oil seed crop, maximizing mustard production and productivity is crucial for reducing edible oil import burden for the country. While, chickpea is the main supplier of protein and has a high nutritional value, its production and productivity enhancement is viatal for achieving food and nutritional security. Hence, maximising the productivity of mustard (Brassica juncea L.) +chickpea (Cicer arietinum L.) Cropping systems is crucial for the country.

Pulses are grown in India annually in of 23.86 million ha with a production of 15.12 million tonnes, with the average productivity of meager 633 kg/ha (Agricultural Statistics at a Glance, 2014). However, the country's demand of pulses by 2020 is to be as huge as 22.3-23.8 million tonnes. Among the potential pulse crops in the country, chickpea (*Cicer arietinum* L.) is a leading pulse crop which is grown in 7.58 million hectares with annual production of 6.91 million tonnes fetching an average productivity of 911 kg/ha (Agricultural Statistics at a Glance, 2014)[1].

Likewise, rapeseed and mustard (*Brassica juncea* L.) stands second in edible oil production in the country with an area of 5.75 million ha and production of 5.80 million tonnes with an average productivity of 1009 kg/ha (Agricultural Statistics at a Glance, 2014). Chickpea and mustard are commonly grown either as sole crops or in an intercropping system in the major growing areas in India. However, not much research efforts have been made to enhance the productivity of the system in these regions. Therefore, an experiment was conducted with the objective to study the effects of irrigation regimes and fertility gradients on the productivity of sole crops of chickpea and mustard and their intercropping as well.

Regarding irrigation statistics, the total area of irrigated land in the world is nearly 284 million hectares. India has the highest irrigated area in the world with 60.85 million hectares followed by China with 57.78 million hectares and USA with 22.39 million hectares [International Commission for Irrigation and Drainage (ICID, 2009)][2]. As water is becoming a scare resource globally, its most efficient use through economical and effective ways of irrigation management is essential for survival of the ever growing population.

In addition to bringing new land into production, productivity of existing farm land should be increased by extending irrigation facilities and by improving existing irrigation systems that operate at less efficiency. Usually most river water is already in use, the main emphasis must be on developing ground water by conserving water obtained from rain. In spite of good sunshine and favourable temperature regimes for crop production, many of these regions has not been able to increase food production and crop productivity to the level required due to shortage of irrigation facilities. This precarious situation leads us to formulate research for most ideal quantiy and most critical stage of the crops.

2. Materials and methods

Field experiments were laid out in split-plot design with three replications during winter season at the Agronomy Research Farm, Amar Singh College, Bulandshahr situated at $28^0 1'$ N, $77^0 1'$E and 228.6 masl). The soil was sandy loam in texture, well drained and of medium fertility with slightly alkaline in reaction (pH 7.4). It was poor in organic carbon (0.33 %), medium in phosphorous (24 kg/ha) and high in potash content (205 kg/ha). The main plot consisted of combination of two factors, viz. cropping system - sole mustard sown at a row distance of 50 cm (C_1), sole chickpea sown at a row distance of 25 cm (C_2) and chickpea + mustard (4:1 ratio of rows)(C_3) and four irrigation levels were proposed keeping chickpea in the view, viz. no irrigation (I_0), irrigation at pre-flowering stage (I_1), irrigation at pod formation (I_2) and irrigation at pre-flowering and pod formation of chickpea (I_3). The sub-plots consisted of three levels of fertilization, viz. 20 N : 40 P_2O_5 : 10 S kg/ha (F_1), 40 N: 60 P_2O_5 : 20 S kg/ha (F_2) and the recommended dose of fertilizers, viz. 20 N : 60 P_2O_5 : 20 S kg/ha (F_3). The test varieties were 'Avrodhi' of chickpea and 'B70' of mustard. Prior to harvesting, to determine the dry weight of the plant and uptake of N, P and S, plants standing in 1 meter length in the middle of the middle row in each treatment plot of sole crops of chickpea and mustard and similarly, plants in one of the middle two rows of chickpea and similar length segment of only row of mustard were earmarked. These earmarked sites were kept moistened by water application overnight prior to digging the plants up to 30 cm depth. After digging out the plants with roots intact the soils stuck to the roots were removed by forced tap water. The plants were counted and seeds were separated and added to the yield obtained from respective plots for computing the yield on hectare basis. The loose plant parts were cut into pieces for easy handling and placed in the oven at 65^0 C for up to 48 hours before their dry weights were recorded. The dry weight per plant as well as on hectare basis were computed from number of plants per meter multiplied by the total length of crop row in a hectare for calculating N, P and S uptake.

In order to calculate the nutrient uptake, the dried plant samples of chickpea and mustard were ground to pass through 40 mesh sieve in a "macro Wiley mill". N, P & S were determined separately. Their uptake (kg ha $^{-1}$) was calculated by the following formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Straw/stover yield (kg/ha) X Nutreint content (\%)}}{100} + \frac{\text{(Seed yield X Nutrient content)}}{100}$$

Land equivalent ratio (LER), which is the relative size of land under a sole crop system, was computed using the following formula :

$$LER = \frac{Y\,ab}{Y\,aa} + \frac{Y\,ba}{Y\,bb}$$

Where,

Yab = Yield of 'a` grown in mixture (a and b)
Yba = Yield of 'b` grown in mixture (a and b)
Yaa = Yield of 'a` in pure stand
Ybb = Yield of 'b` in pure stand

Further, chickpea equivalent yield was calculated by converting the seed yield of mustard into chickpea equivalent yield, based on the prevailing selling prices of the commodities by the following formula :

$$\text{Chickpea equivalent yield} = \frac{\text{Seed yield of mustard (kg/ha)}}{\text{Price of sole crop of mustard Rs/kg}}$$

Entire data obtained on growth and yield was statistically analyzed for computing the critical difference (CD) at 5% significant level as per the technique commonly used for split-plot design**.**

3. Results and discussion

Findings on the impact of cropping systems, irrigation and fertility gradients on the biomass production, N, P and S uptake and seed yield of chickpea and mustard are presented in Table 1 and 2. From the perusal of the data it is clear that the agronomic practices investigated herein had variable effects on various traits in space and time. For example, in the first year, intercropped chickpea (C_3) recorded significantly higher dry matter accumulation, whereas in the second year, there was no effect of cropping systems on biomass production. The drymatter accumulation was higher in intercropped chickpea (C_2) as compared to sole chickpea (C_1). This may be due to slightly wider space and lesser competition prevailed in the intercropped crop as compared to sole chickpea. Likewise, two irrigations in first year and only one irrigation in second year recorded higher drymatter accumulation showing enhanced growth as compared to the crop receiving no irrigation. As far as the effect of nutrients were concerned the fertility level provided by recommended dose of 20 N : 60 P_2O_5 : 20 S kg/ha resulted in significantly higher dry matter accumulation as compared to fertility levels either lower or the further enhanced by N 40 kg/ha.

As irrigation was given later in pre-flowering and pod-filling stage no difference were observed in drymatter accumulation at early stage, however at later stages, the irrigation levels recorded higer dry matter accumulation as compared to no irrigation (I_0). Irrigation enhances the vegetative growth, it is obvious that they increased the drymatter accumulation as compared to no irrigation. The recommended dose of fertilizers on area basis to both the crops (F_3) recorded higher drymatter accumulation as compared to other fertility levels. It is attributed to increased availability of nutrients (Table 1) as per its requirement unlike in other two treatments, which were not suitable to the chickpea. Similar findings were also reported by Verma and Idnani (2012)[4]. The dry matter accumulation in mustard at harvest was not significantly affected by the cropping systems in both the years of experimentation. Further, intercropped mustard (C_3) too did not experience any additional benefit by available space. This may be explained by the fact that the cropping systems did not put any strain on expression of normal growth of the crop in intercropping system. Thus no variability in dry matter was observed due to cropping systems. However, irrigation exhorted significant effect on DMP at harvest such that the application of two irrigations (I_3) resulted in the highest dry matter accumulation. It was closely followed by application of one irrigation at pod filling stage of chickpea in first year and pre-flowering stage of chickpea in second year. In both years, the no irrigation treatments recorded the lowest dry matter accumulation among all levels of irrigation. Application of recommended dose of fertilizers 20 N : 60 P_2O_5 : 20 S kg/ha to both the crops (F_3) recorded the highest dry matter accumulation (Table 1). Similarly, irrigation levels too had significant impact on the total uptake of N, P and S with the seasons exerting variable effects such that the effects of one irrigation at pod filling stage of chickpea (I_2) and 2 irrigations at pre-flowering and pod-filling higher yield over 20 N :40 P_2O_5 :10 S kg /ha (F_1). Similar findings on nutrient response in intercropping system were also reported by Ghosh *et al.* (2009)[5]. The quantum of increase in seed yield due to F_2 and F_3 over F_1 were 10.6% and 16.6% in first year and 9.73% and 20.31% during second year, respectively (Table 3).

Cropping systems had variable effect on the dry matter accumulation per plant in chickpea. In the first year, intercropped chickpea (C_3) recorded significantly higher dry matter accumulation. But in the second year there was no significant effect of cropping systems on the drymatter accumulation. The drymatter stages of chickpea (I_3) were at par with each other, though recorded higher total N uptake as compared to no irrigation (I_0). However, in second year, all the irrigation levels (I_1, I_2 and I_3) were at par with each other recording higher total N as compared to I_0. The total P uptake also followed similar trend as that of total N uptake in both the years. The total S uptake was highest in I_3 and it was closely followed by I_2. However, all the irrigation levels (I_1, I_2 and I_3) recorded significantly higher total S uptake as compared to I_0. The total uptake of N, P and S were significantly higher in F_3 over F_2, and F_2 was significantly superior to F_1 in both the years of experimentation. The irrigation levels recorded higher N, P and S content in seed and thus recorded higher uptake of these nutrients. As the increased levels of irrigation and nutrients increased the seed yield significantly, even with similar content of these nutrients in stalk and stalk yield, higher uptake was observed in irrigation levels as compared to no irrigation (I_0) and 20:40:10 kg N:P_2O_5 :S /ha (F_1) which was the lowest nutrient dose applied as compared to other levels.

Seed yield of mustard was significantly affected by all the treatments tried. Between sole mustard (C_1) and intercropped mustard (C_3), the sole mustard (C_1) recorded significantly higher seed yield as compared to intercropped mustard (C_3). The decrease in the intercropped mustard yield was to the tune of about 59 % as compared to its sole crop. The irrigation levels also recorded significant impact on the seed yield of mustard. Irrigation at pod filling stage proved more beneficial than at other growth stage enhancing the yield by about 12%. One irrigation at pre-flowering stage of chickpea (I_1), one irrigation at pod filling stage of chickpea (I_2) and two irrigations at pre-flowering and pod-filling stages of chickpea (I_3) recorded an increase in seed yield of 4.7%, 12.2% and 11.3% in first year and 8.24%, 12.15% and 15.05% in second year, respectively. The I_3 and I_2 being on par with each other recorded significantly higher yield over I_1 and I_0, which were in turn significantly different from each other.

Recommended dose of fertilizers to both the crops (F_3) recorded significantly higher seed yield over 40 N: 60 P_2O_5 : 20 S kg/ha (F_2) and in turn it recorded accumulation was higher in intercropped chickpea (C_2) as compared to sole chickpea (C_1) (Table 2). This may be due to slightly wider space and lesser competition prevailed in the intercropped crop as compared to sole chickpea. Irrigation levels I_3 in first year and I_2 in second year recorded significantly higher drymatter accumulation. The lowest drymatter accumulation was observed in no irrigation (I_0). The fertility level F_3 recorded significantly higher dry matter accumulation as compared to F_1. Corresponding findings on response to irrigation in intercropping system were also reported by Geren et. al (2008)[6].

Table 1. Dry matter Production (DMP) at harvest and total N, P and S uptake by mustard and chickpea (kg/ha) as influenced by cropping systems, irrigation regimes and fertility gradients

	Mustard				Chickpea			
Treatment	DMP (g/plant)	N	P	S	DMP (g/plant)	N	P	S
Cropping systems								
Sole mustard / Sole chickpea	63.52	76.21	12.32	22.47	12.84	46.97	15.04	7.25
Chickpea+mustard (1:4)	63.63	30.91	4.99	9.12	13.38	46.25	14.67	7.02
CD (P=0.05)	NS	1.84	0.22	0.44	0.55	NS	NS	NS
Irrigation levels								
No irrigation	60.58	49.19	8.21	15.12	11.96	36.57	12.00	5.72
Irrigation at flowering stage	63.92	53.50	8.77	15.87	13.28	46.92	15.34	7.23
Irrigation at pod formation stage	64.99	55.45	8.73	15.88	13.23	49.17	15.51	7.60
Irrigation at flowering+pod formation stage	64.81	56.10	8.90	16.31	13.96	53.77	16.58	7.99
CD (P=0.05)	2.42	2.60	0.31	0.63	0.60	2.83	0.97	0.40
Fertility levels								
N20 P2O5-40 S10	59.05	47.78	8.11	14.97	12.70	43.31	13.85	6.44
N40 P2O5-60 S20	63.27	53.89	8.68	15.90	13.20	47.24	15.01	7.19
N20 P2O5-60 S20 (RDF)	68.40	59.01	9.17	16.51	13.43	49.29	15.71	7.77
CD (P=0.05)	1.41	1.67	0.18	0.29	0.39	1.90	0.65	0.31

Further, since the irrigation was given later in the pre-flowering and pod filling stage, no difference in drymatter accumulation at early stage, however at later stages, the irrigation levels recorded higher drymatter accumulation as compared to no irrigation (I_0). Since irrigation enhances the vegetative growth, it is obvious that they increased the drymatter accumulation as compared to no irrigation. The recommended dose of fertilizers on area basis to both the crops (F_3) recorded higher drymatter accumulation as compared to other fertility levels. It is attributed to increased availability of nutrients as per its requirement unlike in other two treatments, which were not suitable to the chickpea.

Total N uptake was not significantly influenced by the cropping systems in both the years of study. The total P uptake was significantly higher in the first year in sole chickpea (C_2) as compared to intercropped chickpea (C_3) (Table 2). In the second year both the cropping systems were at par with each other. The trend similar to total P uptake was observed in total S uptake due to cropping systems. The total N uptake was not significantly influenced by the cropping systems in both the years of study. This may be attributed to similar N content in seed and stover in both the cropping systems and statistically similar seed and stover yield in both the cropping systems. The slightly lesser population failed to affect both the seed and stalk yield and this coupled with similar content of N in seed and stalk resulted in at par N uptake in both the cropping systems. However the P and S uptake was slightly higher in sole crop of chickpea as compared to intercropped chickpea. This may be ascribed to slightly higher P and S content and also slightly higher seed and stover yield in sole crop of chickpea. These all put together recorded higher P and S uptake in sole chickpea as compared to intercropped chickpea (C_2). Similar findings of crop antagonism in intercropping system was also reported by Mushagalusa *et.al.* (2008)[7].

Out off the four irrigation levels, the two irrigations at pre-flowering and pod-filling stages of chickpea (I_3) recorded significantly higher total uptake of N, P and S in both the years as compared to rest of the treatments. While the least total N, P and S uptake was observed in no irrigation (I_0). The highest total N, P and S uptake was noticed in recommended dose of fertilizers on area basis to both the crops (F_3) followed by 40:60:20 kg N:P_2O_5 :S /ha (F_2). The least total N, P and S uptake was observed in 20:40:10 kg N:P_2O_5 :S /ha (F_1). The irrigation levels and recommended dose of fertilisers on area basis to both the crops (F_3) too recorded higher N, P and S uptake due to higher content of these nutrients in seed and stover. Further the higher seed and stover yield in these treatments coupled with higher content of N, P and S recorded higher uptake of these nutrients as compared to no irrigation (I_0) and lower levels viz. 40:60:20 kg N:P_2O_5 :S /ha (F_2) and

20:40:10 kg N:P_2O_5 :S /ha (F_1), respectively. Similar findings of nutrient response was also reported by Li *et al.* (2008)[8]. As irrigation levels and optimum levels of nutrients result in higher vegetative growth, higher content of nutrients and subsequently higher yield parameters and yield, this will ultimately results in higher total N, P and S uptake in these treatments.

Table 2. Effect of cropping systems, irrigation regimes and fertility gradients on the yield of mustard and chickpea

Treatment	Mustard Seed yield (kg/ha)		Chickpea Seed yield (kg/ha)	
	2005-06	2006-07	2005-06	2006-07
Cropping systems				
Sole mustard	1487.2	1512.7	1063.8	1203.1
Chickpea + Mustard(4:1)	610.5	605.3	1043.2	1195.2
CD at (P=0.05)	27	27	NS	NS
Irrigation levels				
No irrigation	979.8	972.8	876.9	906.8
Irrigation at Flowering	1026.1	1053	1030.6	1231.8
Irrigation at Pod formation	1099.4	1091	1088.4	1270.5
Irrigation at flowering+ Irrigation at Pod formation	1090.1	1119.2	1217.9	1387.8
CD at (P=0.05)	38	38	60.5	60.7
Fertility levels				
N20 P2O5-40 S10	961.5	962.6	980.8	1158.1
N40 P2O5-60 S20	1063.8	1056.3	1073.2	1204.7
N20 P2O5-60 S20 (RDF)	1121.2	1158.1	1106.4	1234.9
CD at (P=0.05)	19	31.2	35.7	50.2

Seed yield was not significantly affected by the cropping systems. And both sole chickpea (C_2) and intercropped chickpea (C_3) recorded yield at par with each other. Among the irrigation levels, two irrigations at pre-flowering and pod-filling stages of chickpea (I_3) recorded significantly higher seed yield as compared to all other treatments. The one irrigation at pre-flowering stage of chickpea (I_1) and one irrigation at pod filling stage of chickpea (I_2) being at par with each other recorded significantly higher yield as compared to no irrigation (I_0). Tyagi *et al.* (2013) reported that frequent irrigation were useful in increasing the seed yield of cropping systems and it could be due to higher nutrient uptake due to two irrigations. The recommended dose of fertilisers on area basis to both the crops (F_3) being at par with 40:60:20 kg N:P_2O_5 : S /ha (F_2) recorded significantly higher seed yield over 20:40:10 kg N:P_2O_5 : S /ha (F_1) in both the years of study. Similar findings were also reported by Shivay, et al. (2014)[9]. The seed yield was not significantly affected by the cropping systems. The lesser number of plants in intercropped chickpea (C_2) was compensated by the better growth and yield attributes.

In contrary, the combinations of C3 and I3 recorded the highest chickpea equivalent yield amongst the different combinations in both the years of experiment. The combinations of C3 and F3, I3 and F3 found to have significantly higher chickpea equivalent yield during second year (Table 3). Therefore, in view of the soil – plant relationship, it is clear that the growth of crops and its potential of production is governed by nutritional availability and management, besides many other relevant factors. Root interface interactions in soil have been a crucial factor for crop growth and thus often an intercropping system has been found as encouraging agronomic practice. The proportion of intercrops apparently depends on the crop canopy, shoot length and rooting system. Hence, a portion of 4:1 ratio of chickpea and mustard intercropping was considered as preferable option by virtue of the characteristics of two crops.

Table 3. Chickpea equivalent yield and land equivalent ratio as influenced by cropping systems, irrigation and fertility gradients.

Treatment	2005–06		2006–07	
	Chickpea equivalent Yield	Land equivalent ratio	Chickpea equivalent yield	Land equivalent ratio
Cropping system				
Sole mustard	743	1.0	756	1.00
Sole chickpea	1 203	1.0	1 063	1.00
Chickpea+mustard(4:1)	1 500	1.41	1 345	1.39
CD (*P*=0.05)	36.93	0.02	36.15	0.04
Irrigation level				
No irrigation	931	1.14	908	1.15
Irrigation at pre-flowering	1 163	1.13	1 038	1.14
Irrigation at pod formation	1 213	1.15	1 089	1.13
Irrigations at pre-flowering +pod formation	1 288	1.13	1 185	1.10
CD (*P*=0.05)	42.64	NS	41.74	NS
Fertility level				
N_{20} $P_2O_{5\text{-}40}$ S_{10}	1 092	1.14	974	1.12
N_{40} $P_2O_{5\text{-}60}$ S_{20}	1 157	1.13	1 067	1.13
N_{20} $P_2O_{5\text{-}60}$ S_{20} (RDF)	1 197	1.13	1 123	1.13
CD (*P*=0.05)	33.25	NS	25.96	NS

RDF=Recommended dose of fertilisers

However, the gross return, net return and B:C ratio were significantly higher in intercropped chickpea and mustard in 4:1 row ratio in comparison to their sole crops. Since the investments in intercropped systems did not differ significantly, the higher yield of the system added to increased gross return, net return and B:C ratio.

The sole chickpea withhigher value for its produce was significantly superior to sole mustard. Among the irrigation levels, 2 irrigations at pre-flowering and pod-formation stages of chickpea recorded the highest gross return and net return as compared to other irrigation treatments. This was due to higher seed yield of both the crops in this treatment. When a particular treatment increases yield of crops it tends to increase the gross and net returns. But the highest B:C ratio was recorded in one irrigation at pod filling stage of chickpea. All the irrigation levels recorded significantly higher values of these as compared to no irrigation. Since one additional irrigation proportionately increase the cost as compared to output in terms of seed yield and thus B:C ratio tended to be lower in case of 2 irrigations as compared to 1 irrigation. Application of recommended dose of fertilisers on area basis to both the crops recorded significantly higher gross return, net return and B: C ratio as compared to 40-60-20 kg N, P2O5 and S/ha which was in turn significantly superior to 20-40-10 kg N, P2O5 and S/ha. The fertiliser requirement of crops on the basis of their needs in F3 recorded higher seed yield as compared to other fertility levels, it in turn showed higher gross return, net return and B: C ratio.

Kour *et al.* (2013)[10] also reported higher net returns and B:C ratio due to intercropped chickpea. The treatment combinations of C_3 and I_3 recorded the highest chickpea equivalent yield among the different combinations in both the years of the experiment. While the combinations of C3 and F3, I3 and F3 recorded significantly higher chickpea equivalent yield during second year. With respect to the soil-water-plant relationship, it is well known that the growth of crops and its potential for production are governed by moisture availability and management, besides many other relevant factors. Root interface interactions in soil have been an influential and additional factor for crop growth and thus often an intercropping system has been found as an encouraging agronomic technology. The combination and proportion of intercrops obviously depends on shoot length, crop canopy and routing system. Hence portion of 4:1 ratio of chickpea and mustard intercropping system was considered as preferable option by virtue of the characteristics of two crops.

4. Conclusion

To conclude from the results of the investigation, the system of inter cropping of chickpea and mustard in 4:1 row ratio was significantly superior to sole crops of either chickpea or mustard. Among chickpea and mustard, cultivation of chickpea was better in comparison to mustard from the economic point of view. From the practical point of view, the findings revealed that when the two irrigations are expected to be available, their application during pre-flowering and pod filling stage of chickpea would result in higher yield. Further, the recommended dose of fertilisers (20 N : 60 P_2O_5 : 20 S kg/ha) application to both the crops was found superior in comparison to either 20 N :40 P_2O_5:10 S kg /ha or 40 N :60 P_2O_5:20 S kg ha. The biomass production and the nutrient uptake by chickpea and mustard crops were found well tuned with the irrigation regimes and fertilizer levels.

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