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Satybhan Singh
a. Department of Agronomy, A.S. (P.G.) College, Lakhaoti, Bulandshahr, Utter Pradesh, India
b. Department of Agricultural Sciences & Engineering, IFTM University, Moradabad, Utter Pradesh, India

OVS Thenua
Department of Agronomy, A.S. (P.G.) College, Lakhaoti, Bulandshahr, Utter Pradesh, India

Virendra Singh
Department of Agricultural Sciences & Engineering, IFTM University, Moradabad, Utter Pradesh, India

Correspondence
Satybhan Singh
a. Department of Agronomy, A.S. (P.G.) College, Lakhaoti, Bulandshahr, Utter Pradesh, India
b. Department of Agricultural Sciences & Engineering, IFTM University, Moradabad, Utter Pradesh, India

Effect of phosphorus and sulphur fertilization on yield and quality of mustard & chickpea in intercropping system under different soil moisture regimes

Satybhan Singh, OVS Thenua and Virendra Singh

Abstract
This field study was conducted during *Rabi* season 2009-10 and 2010-11 to study the effect of different levels of phosphorus, sulphur, irrigation and intercropping on yield and quality of mustard and chickpea at agronomic research farm of Amar Singh (P.G.) College, Lakhaoti, Bulandshahr (U.P.). On the basis of results of the experiment it may be concluded that the 60 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} with two time irrigation, one each at pre-flowering and grain filling stages of mustard in mustard and chickpea intercropping system could be necessary for obtained higher yield, oil content in mustard, protein content in chickpea and maximum benefit: cost ratio.

Keywords: Mustard, chickpea, phosphorus, sulphur, intercropping, irrigation

Introduction
India in one of the leading oilseed producing country in the world but now it is unable to fulfil the edible oil requirement of its burgeoning population. Indian mustard (*Brassica juncea* L.) is a major winter oilseed crop belongs to the family of *Cruciferae*. Rapeseed and mustard are important oilseed crops which rank third in vegetable oils after soybean and palm (USDA, 2011) [15]. Rapeseed-mustard (*Brassica junce*a L.) in world production India ranks third after Canada and China. Its seed contains 37- 49% oil (Singh *et al.* 2014) [10]. The oil and seeds are used as condiment in the preparation of pickles and for flavouring curies and vegetables. The mustard oil is utilized for human consumption throughout northern India in cooking and frying purposes. It is also used in the preparation of hair oils and medicines. The oil cake is used as cattle feed and manure, which contains about 4.9 percent nitrogen, 2.5 percent phosphorus and 1.5% potash [Singh *et al.* 2014] [10].

Mustard is the third most important oilseed crops after soybean and groundnut in India occupying 6.65 million-hectare acreage, 7.88 million tonnes production and 1,185 kg ha^{-1} productivity (Anonymous 2015) [1]. Major states producing mustard are Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal and Gujarat. Rajasthan ranks first in both area and total production of mustard. Gujrat has the highest productivity (1485 kg ha^{-1}) of rapeseed and mustard. Among the different states, Uttar Pradesh alone produces about 20 percent of total rapeseed and mustard production in India (Singh *et al.* 2014) [10]. The area under mustard in Uttar Pradesh are 0.66 million hectares with production of 0.74 million tones and productivity 1112 kg ha^{-1} (Anonymous 2015) [1]. India's per capita edible oil consumption is currently estimated at 17.18 kg and vegetable oil consumption of the world average is 24.86 kg (USDA 2016) [16].

The continuous mining of nutrients from soils coupled with inadequate and imbalanced fertilizer use has resulted in emergence of multi nutrient deficiencies. Mainly at least six nutrients (N.P.K.S. Zn and B) were observed deficient in Indian soils. Phosphorus is constituent of sugar phosphates, nucleotides, nucleic acid, coenzymes and phospholipids. The process of anabolism and catabolism of carbohydrates proceed when organic compounds are esterised with phosphoric acid (Reddy and Reddy, 2001) [7]. It is closely related to cell division and development. In legumes it enhances the activity of rhizobium and increase the formation of root nodules, thus it helps in fixing of more atmospheric nitrogen (Yawalkar, *et al.* 1977) [18]. Sulphur is involved directly or indirectly in different metabolic pathways of plants and play important role in the metabolic activities. The involvement of sulphur is an important component of several enzymes and metabolic processes in plants (Lakkineni and Abrol 1994) [5]. The seed yield and oil quality of mustard can be improved by the proper application of phosphorus and sulphur, Singh and Thenua (2016) [12].

Pulses are rich source of protein for the vegetarian. Chickpea is the important pulse crop grown in larger area and production in the world. Chickpea ranks in first position in area (6.93 million hectare) and production (5.39 million tonnes) in India. It constitutes 32% and 40% of area and production of total pulse grown in India. Chickpea and mustard have lion's share in pulse and oilseeds, respectively. These crops are often grown in association in North and North-Western parts of India. One of the main reason of low productivity of this system is inadequate nutrition specially phosphorus and sulphur. The phosphorus and sulphur requirement of the crops further influenced by available moisture conditions of the soil.

The objective of this study was to examine the effect of phosphorus and sulphur fertilization on mustard + chickpea intercropping system under different soil moisture regimes.

Material and Methods

Field experiments were conducted at the research farm of A.S. (P.G.) College, Lakhaoti, Bulandshahr (U.P.) during the *Rabi* season 2009-10 and 2010-11. The design applied for statistical analysis was carried out with split plot design, with four levels of Irrigation (I_0- Control, I_1- one irrigation at pre-flowering stage of mustard, I_2- one irrigation at grain filling stage of mustard, I_3- two irrigations one each at pre-flowering and grain filling stages of mustard) in main plots, three levels of Phosphorus (0, 30, and 60 kg ha^{-1}) and three levels of Sulphur (0, 20, and 40 kg ha^{-1}) in sub plots, respectively. Thus, 36 treatment combinations were tested and replicated thrice. Both crops were sown in lines and lines were drawn with the help of rope manually maintaining row to row distance of 45 cm. Mustard was grown with chickpea in 1: 1 row ratio intercropping. The chickpea was grown to replace of mustard crop in alternate row. 60 kg Nitrogen/ha was applied through Urea, in two equal splits (1/2) basal and other half 30 days after sowing of the crop while the full doses of phosphorus and sulphur were applied as basal dose as per treatments. The soil of farm is well levelled, sandy loam in texture and slightly alkaline in reaction. It analyzed low both in organic carbon and total nitrogen. It was medium in available phosphorus and potash. The farm is situated at 28.4˚ N latitude, 77.10˚ E longitude and altitude of 207.3 meters above the mean sea level.

Result and Discussion

Mustard

The yield attributing traits number of siliquae $plant^{-1}$ (263.94), number of seeds $siliquae^{-1}$ (13.30) and 1000-seeds weight (4.70g) were significantly increased when field was irrigated twice. The probable reasons for these findings optimum water availability in root zone of mustard. The biological yield (42.94 q ha^{-1}), seed yields (11.79 q ha^{-1}) and harvest index (27.48) were significantly increased with the two time irrigation over the rest treatments (Table 1). It is attributed due to the number of primary and secondary branches increased. The same findings also reported by Yadav, *et al.* (2010) [17]. The oil content (40.12%) was significantly increased with the two irrigations in mustard + chickpea intercropping (Table 1). It is attributed due to the more availability of moisture to mustard plant increased in seed yield (q ha^{-1}) and oil content in grain also.

Table 1: Yield attributes, yields and oil content in mustard seed as influenced by phosphorus and sulphur fertilization in mustard + chickpea intercropping system under different irrigation schedules.

Treatments	No. of siliquae $plant^{-1}$	No. of seeds $siliquae^{-1}$	Test weight (g)	Biological yield (q ha^{-1})	Grain yield (q ha^{-1})	H.I. (%)	Oil content in seed (%)
Irrigation							
I_0	187.56	8.77	3.57	27.13	7.48	27.52	37.60
I_1	211.39	10.56	4.03	33.00	9.13	27.44	38.71
I_2	233.28	11.83	4.24	30.67	10.36	27.46	39.09
I_3	263.94	13.30	4.70	42.94	11.79	27.48	40.12
SE(d)	1.89	0.11	0.03	0.28	0.12	0.06	0.03
CD(P=0.05)	4.11	0.23	0.07	0.62	0.26	0.14	0.06
Phosphorus							
P_0	209.95	10.57	3.87	32.56	8.93	27.41	38.61
P_{30}	222.99	11.09	4.13	35.48	9.83	27.49	39.88
P_{60}	239.18	11.74	4.41	38.22	10.52	27.54	39.91
SE(d)	1.82	0.12	0.04	0.31	0.13	0.07	0.03
CD(P=0.05)	3.58	0.24	0.07	0.61	0.26	NS	NS
Sulphur							
S_0	214.54	10.75	3.94	32.81	9.01	27.49	38.61
S_{20}	225.44	11.21	4.19	36.23	9.96	24.47	39.00
S_{40}	233.14	11.44	4.28	37.22	10.31	27.47	39.04
SE(d)	1.82	0.12	0.04	0.31	0.13	0.07	0.03
CD(P=0.05)	3.58	0.24	0.07	0.61	0.26	NS	0.06

The yield contributing characters of mustard as like, number of siliquae $plant^{-1}$ (239.18), number of seeds $siliquae^{-1}$ (11.74) and 1000-seeds weight (4.41g) were found significantly superior when field is fertilized with 60 kg P_2O_5 ha^{-1} over the other treatments. It is attributed due to the increase in availability of P_2O_5 to mustard plant. The results are in conformity with those already reported by Yadav, *et al.* (2010) [17], Singh and Thenua (2016) [12] and Kumar, *et al.* (2017) [4]. The seed yield (10.52 q ha^{-1}) and total biological yield (38.22 q ha^{-1}) were significantly increased with the 60 kg P_2O_5 ha^{-1} (Table 1). Mumber of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$ and 1000-seed weight significantly increased with the application of 60 kg P_2O_5 ha^{-1}. It is increased due to the more availability of P_2O_5 to mustard plant, while the harvest index and oil content in grain were failed to touch the level of significance. The same results also reported by Yadav, *et al.* (2010) [17], Singh and Thenua (2016) [12] and Kumar, *et al.* (2017) [4].

The number of siliquae plant^{-1} (233.14), no. of seeds siliquae^{-1} (11.44) and 1000-seeds weight (4.28g) of mustard were recorded significantly highest with the application of 40 kg S ha^{-1} over the other treatments (Table 1). It is attributed because sulphur increases nitrogen availability to mustard plant and sulphur is a main constituent of chlorophyll and this made more food material in the presence of sunlight, CO_2 and sufficient moisture which is translocated to seed. The same findings also reported by Kumar, *et al.* (2002) [3], Singh and Thenua (2016) [12]. Grain yield (10.31 q ha^{-1}), Biological yield (37.22 q ha^{-1}) and oil content in seed (39.04%) were recorded significantly higher with 40 kg sulphur was applied while harvest index was observed non-significant with the sulphur application. It is attributed because sulphur increases nitrogen availability to mustard plant and sulphur is a main constituent of chlorophyll and this made more food material in the presence of sunlight, CO_2 and sufficient moisture which is translocated to seed. The same findings also reported by Singh, *et al.* (2010) [9] Lakshman, *et al.* (2010) and Singh and Thenua (2016) [12].

Chickpea

The number of pods plant^{-1} (26.58) and number of seeds pod^{-1} (1.76) of chickpea in mustard + chickpea intercropping significantly increased with the application of two irrigations. It is attributed due to the sufficient soil moisture was available in root zone. The same findings also reported by Singh *et al.* (2010) [9] and Thenua *et al.* (2010) [14]. Grain yield (9.46 q ha^{-1}), biological yield (20.02 q ha^{-1}) and test weight (126.45g) of chickpea were significantly increased with the application of two irrigations (Table 2). It is attributed due to adequate moisture in root zone and the chickpea plant absorbed sufficient nutrient from the soil and long duration of vegetative phase ultimately the photosynthesis process prolonged. The same findings also reported by Singh *et al.* (2010) [9] and Thenua *et al.* (2010) [14]. The harvest index (49.41%) and the protein content (20.06%) in grain of chickpea were significantly increased with the application two irrigations in mustard + chickpea intercropping (Table 2). It is attributed due to the availability of proper soil moisture increased the availability of plant nutrients. The same findings also reported by Singh, *et al.* (2010) [9].

Table 2: Yield attributes, yields and protein content in chickpea grain as influenced by phosphorus and sulphur fertilization mustard + chickpea intercropping system under different irrigation schedules.

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test wt. (g)	Grain yield (q ha^{-1})	Biological yield (q ha^{-1})	H.I. (%)	Protein content in seed (%)
Irrigation							
I_0	14.70	1.056	121.39	4.63	9.37	47.29	19.45
I_1	19.61	1.347	123.50	8.50	17.69	47.54	19.60
I_2	25.09	1.753	126.39	9.35	19.66	48.08	19.76
I_3	26.58	1.762	126.45	9.46	20.02	49.41	20.06
SE(d)	0.28	0.005	0.38	0.16	0.321	0.25	0.04
CD(P=0.05)	0.61	0.010	0.82	0.34	0.47	0.55	0.08
Phosphorus							
P_0	19.86	1.411	123.50	7.38	15.46	48.07	19.49
P_{30}	21.76	1.488	124.33	7.92	16.42	48.41	19.76
P_{60}	23.54	1.541	125.46	8.65	18.18	48.76	19.89
SE(d)	0.31	0.018	0.45	0.16	0.23	0.45	0.04
CD(P=0.05)	0.62	0.035	0.89	0.34	0.46	NS	0.08
Sulphur							
S_0	20.67	1.436	123.50	7.36	15.26	48.49	15.59
S_{20}	21.92	1.472	124.46	8.13	16.98	48.02	19.73
S_{40}	22.57	1.516	127.84	8.47	17.81	47.74	19.84
SE(d)	0.31	0.018	0.45	0.16	0.23	0.30	0.04
CD(P=0.05)	0.62	0.035	0.89	0.34	0.46	NS	0.08

The number of pods plant^{-1} (23.54), number of seeds pod^{-1} (1.45) and test weight (125.46g) of chickpea were recorded significantly higher with the application of 60 kg P_2O_5 ha^{-1}. It is attributed due to close relation of phosphorus with cell division which ultimately increased the number of pods plant^{-1}, no. of grain pod^{-1} and test weight. The same findings also reported by Bahadur, *et al.* (2002). The maximum grain yield (8.65 q ha^{-1}) and biological yield (18.18 q ha^{-1}) of chickpea were recorded with the application of 60 kg P_2O_5 ha^{-1} when chickpea intercropped with mustard, while harvest index was observed non-significant (Table 2). It is attributed due to the increase in number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight, ultimately grain and biological yield of chickpea, were increased. The same findings also reported by Singh (2017) [4] and Shukla, *et al.* (2017). Protein content in grain (19.89%) was significantly increased with the application of 60 kg P_2O_5 ha^{-1} (Table 2). It is attributed due to the phosphorus enhances the activity of rhizobium and increase the formation of root nodules, thus it helps in fixing of more atmospheric nitrogen. Because of, nitrogen is a main constituent of protein that is more protein content was accumulated in chickpea grain. The relationship in between the nitrogen fixation and protein synthesis in leguminous crops is linear. The same findings also reported by Thenua, *et al.* (2010) [14] and Singh (2017) [4].

The number of pods plant^{-1} (22.58), seeds pod^{-1} (1.516) and test weight (127.84) were significantly increased with the application of 40 kg S ha^{-1} (Table 2). It is attributed due to the more nutrient availability to chickpea crop ultimately increased the number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight. The same findings also reported by Singh (2017) [4]. The seed yield (8.47 q ha^{-1}) and biological yield (17.81 q ha^{-1}) of chickpea intercrop with mustard was significantly increased with the application of 40 Kg S ha^{-1} (Table 2). It is attributed due to the number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight were significantly increased with the application of 40 kg S ha^{-1} and ultimately the seed yield (q ha^{-1}) and biological yield (q ha^{-1}) were increased, but the harvest index was noted non-significant with the sulphur application. The same findings

also reported by Singh, *et al.* (2010) [9], Thenua, *et al.* (2010) [14], and Singh (2017) [4]. Protein content (19.84) in chickpea grain was significantly increased with the application of 40 kg S ha^{-1} (Table 2). It is increased due to the sulphur stimulates the nodule formation in leguminous plants. It favours the increase in soluble organic nitrogen and decrease in quantity of insoluble nitrogen, and sulphur is a constituent of amino acid which increased the protein content in chickpea grain.

Mustard Equivalent Yield (MEY)

Mustard equivalent yield in intercropping of mustard + chickpea was significantly superior (22.32 q ha^{-1}) with two irrigations over the rest treatments of irrigation (Table 3). Various phosphorus doses were significantly affected the mustard equivalent yield in mustard + chickpea intercropping. Application of 60 kg P_2O_5 ha^{-1} was increased in equivalent yield (20.13 q ha^{-1}) over other treatments (Table 3). Highest dose of sulphur 40 kg S ha^{-1} was received higher mustard equivalent yield (19.72 q ha^{-1}) over control (Table 3).

Table 3: Mustard equivalent yield (q ha^{-1}) and Economics of both crops as influenced by phosphorus and sulphur fertilization mustard + chickpea intercropping system under different irrigation schedules.

Treatments	Mustard equivalent yield (q ha^{-1})	Gross Return	Net Return	Benefit: Cost ratio
Irrigation				
I_0	12.56	33298	16573	0.99
I_1	18.58	49234	32218	1.89
I_2	21.02	55697	38077	2.16
I_3	22.31	59121	40901	2.24
SE(d)	0.27	-	-	-
CD(P=0.05)	0.59	-	-	-
Phosphorus				
P_0	17.14	45415	28545	1.68
P_{30}	18.59	49253	31825	1.82
P_{60}	20.13	53352	35457	1.96
SE(d)	0.33	-	-	-
CD(P=0.05)	0.66	-	-	-
Sulphur				
S_0	17.19	45550	28468	1.65
S_{20}	18.95	50206	32803	1.87
S_{40}	19.72	52264	34557	1.94
SE(d)	0.33	-	-	-
CD(P=0.05)	0.66	-	-	-

Economics

Gross income (Rs ha^{-1})

Various irrigation schedules were significantly influenced the gross income Rs ha^{-1} and with the application of two irrigation was obtained Rs 55697/= ha^{-1} over control, respectively (Table 3). Various dose of phosphorus were significantly reflected the gross income Rs ha^{-1} and with the application of 60 kg P_2O_5 ha^{-1} was calculated Rs 53352/= ha^{-1} gross income, respectively (Table 3). Different doses of sulphur were significantly influenced the gross income Rs $ha^{-1}$and with the application of 40 kg S ha^{-1} was obtained significantly higher gross income Rs 52264/= ha^{-1} over control, respectively (Table 3).

Net income (Rs ha^{-1})

Various numbers of irrigation were significantly influenced the net profit in mustard + chickpea intercropping in 1: 1 row ratio and with two irrigation was obtained significantly more net return Rs 40901/= over other irrigation treatments, respectively (Table 3). Various level of phosphorus were significantly reflected the net income (Rs ha^{-1}) and the using 60 kg P_2O_5 ha^{-1} was obtained Rs 35457/= ha^{-1}, respectively (Table 3). Various levels of sulphur were significantly influenced the net income Rs ha^{-1} and with the application of 40 kg S ha^{-1} was obtained Rs 34557/= over untreated plot with sulphur, respectively (Table 3).

Benefit: Cost ratio

Various irrigation schedules were significantly reflected the benefit: cost ratio in mustard + chickpea intercropping and the application of two irrigations the benefit: cost ratio was obtained significantly higher 2.24, respectively (Table 3). Higher dose of phosphorus 60 kg ha^{-1} was significantly recorded the benefit: cost ratio 1.96, respectively (Table 3). Benefit: cost ratio was significantly influenced with application of various level of sulphur and with the application of 40 kg S ha^{-1} was recorded significantly higher benefit: cost ratio 1.94 followed by the application of 20 kg S ha^{-1} over untreated plot with sulphur (Table 3).

Conclusion

On the basis of two years field experiment made during the *Rabi* 2009-10 and 2010-11, it may be concluded that the application of two time irrigation, one each at pre-flowering and grain filling stage of mustard with 60 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} was very effective and good combination of moisture and nutrients for mustard + chickpea intercropping system in sandy loam soils.

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