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SS Nawale
Ph.D. Student, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

PT Kolekar
Assistant Professor, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

AV Solanke
Professor, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Correspondence
SS Nawale
Ph.D. Student, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Soybean followed by wheat cropping system under variable sowing windows and fertilizer levels

SS Nawale, PT Kolekar and AV Solanke

Abstract
A field experiment was conducted to study the effect of sowing dates and fertilizer levels on productivity and nutrient uptake of soybean-wheat cropping system. The productivity of soybean was higher sowing in meteorological week 24 and application of 100 per cent RDF to wheat crop (29.02, 29.80 and 29.41 q ha^{-1} and 38.30, 38.92 and 38.61 q ha^{-1}) during both the years and pooled mean, respectively and it was at par with meteorological week 25 and application of 75 % RDF. Among the different sowing date treatments to soybean and 100 % RDF treatment to wheat crop recorded. The highest nutrient uptake in soybean and wheat (95.81, 96.04, 17.66, 17.69, 78.88, 80.82 and 100.54, 102.13, 21.45, 22.59, 117.10, 116.54 kg ha^{-1}, respectively) were recorded by sowing in meteorological week 24 to soybean and 100 % RDF to wheat crop. Sowing in meteorological week 24 and 100 % RDF to wheat crop resulted in higher available NPK after soybean (187.67, 189.91, 17.16, 17.64, 201.46 and 205.97 kg ha^{-1}) after soybean and wheat harvest (161.62, 162.86, 16.52, 17.88, 277.55 and 280.45 kg ha^{-1}) respectively. The result of experiment revealed that sowing in meteorological week 24 to soybean and 100 % RDF to wheat found higher productivity and uptake of nutrients of soybean-wheat cropping system.

Keywords: Meteorological weeks, quality yield and nutrient uptake

Introduction
Soybean (*Glycine max* L.) is important pulse as well as oil seed crop. It is believed to be originated in China in around 2838 B.C. It belongs to the family leguminaceae and sub family papilionaceae. Soybean was introduced in sixties as a supplementary oilseed crop to overcome the edible oil shortage in the country. In India, soybean has emerged as main oilseed crop in a short span of time. It is termed as wonder bean because it contains 40 per cent good quality protein rich lysine and 20 per cent oil high in essential fatty acid (Omega-6 and Omega-3). Additionally, 26 per cent carbohydrates, 4 per cent minerals and 2 per cent phospholipids (Halwankar *et al.*, 1992) [3]. That's why it is known as a wonder crop and miracle crop Golden Bean. Soybean in India has become a leading oil seed crop with 47 and 25 % contribution towards the total oil seeds and edible oil production in the country during 2012-13. In Maharashtra, it is grown over an area of 32.19 lakh hectare with total production 46.70 lakh tonnes with average productivity of 1451 kg^{-1} in 2012-13. This means a favourable soil and climatic conditions are made available for the expression of genetic potential. As the sowing delayed thermal heat units reduced (Hari Ram *et al.*, 2010) [4]. This congenial condition for crop growth developed by date of sowing.

Wheat (*Triticum aestivum* L.) is a native of Abyssinia or Turkey belonging to Gramineae family. It is known to India since prehistoric time and known as king of cereals. Wheat is grown across a wide range of environments around the world. In fact it has the broadest adaption along the cereal crops species. The crop has considerable importance as a food of mankind, providing ample calories and proteins to the growing population, hence more land is devoted world wide to the production of wheat than to the any other commercial crops. The reason why wheat is considered to be very important food grain due to its bread making quality which is a result of presence of glutein in wheat grain. Wheat is being extensively cultivated all over the world, especially in China, India, U.S.A., Pakistan, Australia and Netherland. In India, Uttar Pradesh, Punjab, Haryana, Bihar and Madhya Pradesh are the leading states in wheat production. India, in spite of being a second most wheat producing country has a very low productivity as compared to other countries. Wheat (*Triticum aestivum* L.) is an important cereal crop cultivated all over the world In India, the area and production of wheat is 30 million ha and 93.51 million tonnes with productivity of 3117 kg ha^{-1}. In Maharashtra area and production of wheat is 7.73 lakh ha and 11.81 lakh tonnes with productivity of 1528 kg ha^{-1} which is less than national average (Anonymous, 2013) [1].

The enhanced yield in future would have to be harvested from vertical rather than horizontal expansion of net cropped area. Enhanced agricultural production is depleting the finite nutrient resource from the soil has been shown to potentially degrade the resource base. Total nutrients (N, P_2O_5 and K_2O) consumption will be estimated as 30-35 million tonnes in 2025 A.D. The gap between nutrients removal by crops and addition through fertilizers would remain at about 10 million tonnes of nutrients per annum. The fertilizers production in the country lags behind actual consumption and import bill for augmenting the locally manufactured fertilizers is staggeringly high.

Material and Methods

An agronomic investigation entitled, "Performance of soybean based cropping systems under variable sowing windows and fertilizer levels" was carried out during 2013-14 and 2014-15 at the Instructional Farm of Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India).

The experiment was laid out in split plot design with three replications. The main plot treatment comprised of three cropping sequences *viz.*, C_1 : soybean-wheat, C_2 : wheat-chickpea and C_3 : soybean-potato and three sowing date treatments *viz.*, M_1 : Meteorological week 24 (11-17 June), M_2 : Meteorological week 25 (18-24 June) and M_3 : Meteorological week 26 (25 June-1 July). Whereas, subplot treatments were comprised of three fertilizer levels *viz.*, F_1 : 50 % RDF, F_2 : 75 % RDF and F_3 : 100 % RDF.

The experimental soil was sandy clay loam in texture, low in available nitrogen (155.11 kg ha^{-1}), medium in available phosphorus (14.27 kg ha^{-1}) and high in available potassium (348.24 kg ha^{-1}). The soil was moderately alkaline in reaction (pH 8.45), the electrical conductivity, organic carbon 0.40 dSm^{-1} and 0.49 per cent, respectively.

Results and Discussion

Performance of *kharif* soybean

Yield

Sowing in meteorological week 24 proved its optimum sowing time by recording significantly higher growth attributes reflected in higher yield attributes *viz.*, number of pods $plant^{-1}$ (69.17 and 69.49), pod weight $plant^{-1}$ (26.22 and 27.11), number of seeds $plant^{-1}$ (181.13 and 182.71), seed weight $plant^{-1}$ (16.19 and 17.22 g), hundred seed weight (13.93 and 14.90 g), seed yield (29.02, 29.80 and 29.41 q ha^{-1}) during both the years and on pooled mean and it was at par with meteorological week 25 (Table 1 and 2). This might be because of the sowing time is crucial factor that determines the crop yield and has a unique importance in maximum utilization of natural resources like sunlight and available moisture. The growth phases coincide with environmental conditions in order to produce higher crop yield. Sowing earlier or later than the optimum period results in imbalanced apportioning of assimilates into vegetative and reproductive parts resulting in low yields. This means a favourable soil and climatic conditions are made available for the expression of genetic potential. As the sowing delayed thermal heat units reduced. These results are in conformity with the results obtained by Halwankar *et al*. (1989) [2], Yadahalli and Palled (2004) [16], Hari Ram *et al.* (2010) [4], Karhale *et al*. (2014) [6] and Thombre (2014) [12].

Quality studies

The protein and oil content was found non-significant and protein yield (12.35, 12.73 and 12.53 q ha^{-1}) as well as oil yield (10.07, 10.00 and 9.99 q ha^{-1}). This might be because of soybean seed were accumulate higher concentration of nitrogen which increases the protein and oil synthesis (Table 3). Similar results were recorded by Halwankar *et al.* (1989) [2], Sankpal *et al.* (1991) [10], Jasani *et al.* (1994) [5] and Thombre (2014) [12].

Total nutrient uptake

Sowing of soybean in meteorological week 24 registered significantly higher total uptake of nitrogen (95.81 and 96.04 kg ha^{-1}), phosphorus (17.66 and 17.69 kg ha^{-1}) and potassium (78.88 and 80.82 kg ha^{-1}) and it was at par with meteorological week 25. The lowest uptake was found in meteorological week 26 (Table 4). The nutrient uptake depends upon the soil pH, oxidation potential rhizodeposition, nutrient concentration and root exudates. This chemical changes in the root rhizosphere was significantly influenced on uptake by plants. This might be because of the sowing time is a crucial factor that determine the crop yield and has a unique importance in maximum utilization of natural resources like sunlight and available moisture. The growth phases coincide with environmental conditions in order to produce higher yield of crop and uptake. Sowing earlier or later than the optimum period results in imbalanced apportioning of assimilates into vegetative and reproductive parts resulting in low uptake. These results are in conformity with the results obtained by Sankpal (1991) [10], Yadahalli and Palled (2004) [16], Hari Ram *et al.* (2010) [4] and Thombre (2014) [12].

Performance of wheat

Yield

The higher level of fertilizer (100 % RDF) showed its superiority over reduced level of fertilizers (75 and 50 % RDF) by recording maximum yield attributes in wheat crop during both the years. Application of 100 per cent recommended dose of fertilizer to succeeding wheat crop preceded by *kharif* soybean registered significantly length of panicle (8.10 and 9.08 cm), panicle girth (4.54 and 3.82), panicle weight $plant^{-1}$ (3.01 and 3.61 g), grain weight $panicle^{-1}$ (2.40 and 3.01 g), 1000 grain weight (42.53 and 43.66 g) during the period of investigation (Table 5). The maximum and significantly higher grain yield of (40.12, 40.92 and 40.52 q ha^{-1}) was achieved with 100 per cent recommended dose of fertilizer and it was at par with 75 per cent recommended dose of fertilizer lowest yield was found in 50 per cent recommended dose of fertilizer during first, second year and pooled mean, respectively (Table 6).

This indicate that growing of wheat crop after *kharif* season saves 25 per cent recommended dose of fertilizer, because of balance nutrition to *kharif* soybean through GRDF creates favourable environment in the root rhizosphere of wheat crop to absorb more nutrient and moisture by improving the soil porosity, moisture holding capacity and nutrient use efficiency, which leads to increase the growth and yield attributes of wheat crop. These results are in corroborated with Kumbhar *et al*. (2007) [7], Ramesh *et al.* (2009) [9] and Pacharne (2014) [8].

Quality studies

The higher levels of fertilizer (100% RDF) registered maximum protein and glutein content in wheat grain because growing of wheat crop preceded by *kharif* soybean with 100 per cent recommended dose of fertilizer accumulates more nitrogen and phosphorus in wheat grain which favourably

improve the quality of wheat (Table 7). Since potash fertilizer can improve the quality of wheat by increasing the content of important essential amino acids especially lycine and threonine, it is recommended that potash in combination with nitrogen should be applied to wheat crop for improving the quality and quantity of wheat protein and to boost up grain production per unit area. Similar findings were reported by Tomar *et al.* (2007) [13] and Pacharne (2014) [8].

Total nutrient uptake

The residual effect of *kharif* soybean alongwith sowing in meteorological week 24 recorded significantly maximum uptake of nutrients by wheat crop during both the years.

The sowing in meteorological week 24 to preceding crop *kharif* soybean improves the soil fertility status in respect of soil available nutrients and organic matter which is the energy sources for soil microorganisms, these reflect on more availability of nutrients to succeeding crops. Similarly because of more nutrients availability, the yield attributes and yield of wheat was increased and removed more nutrients from soil compared to rest of the treatments (Table 8). Similar findings were reported by Verma *et al.* (2005), Vidyavathi *et al.* (2011) [14] and Singh *et al.* (2012) [11].

The higher level of fertilizer (100 % RDF) to succeeding wheat crop preceded by *kharif* soybean exhibited significantly higher total uptake of nitrogen, phosphorus and potassium by these crops during both the years. This might be due to combine effect of residual fertility build up by *kharif* soybean and higher level of fertilizer to the succeeding crops increase the availability of nutrients in the root rhizosphere, leads increase uptake of nutrients throughout the crop growth period. These results are agreements with those reported by Walia *et al.* (2009) [15] and Vidyavathi *et al.* (2011) [14].

Table 1: Yield attributes of soybean as influenced by different treatments

Treatments	No. of pods plant^{-1}		Pod wt. plant^{-1} (g)		No. of seeds plant^{-1}		Seed wt. plant^{-1} (g)		Hundred seed wt. (g)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
M_1 : MW-24 (11-17 June)	69.17	69.49	26.22	27.11	181.13	182.71	16.19	17.22	13.93	14.90
M_2 : MW-25 (18-24 June)	54.11	56.81	23.40	24.19	132.92	134.50	13.63	14.55	11.51	12.73
M_3 : MW-26 (25 June-1 July)	39.05	44.13	20.58	21.27	84.71	86.09	11.07	11.88	9.09	10.56
S.Em ±	5.02	4.12	0.98	0.92	16.49	16.23	0.85	0.89	0.81	0.89
C.D. at 5 %	15.06	12.68	2.82	2.92	48.21	48.41	2.56	2.67	2.42	2.17
General Mean	54.11	56.81	23.40	24.19	132.92	134.43	13.63	14.55	11.51	12.73

Table 2: Seed and straw yield per hectare of soybean as influenced by different treatments

Treatments	Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean
M_1 : MW-24 (11-17 June)	29.02	29.80	29.41	35.11	35.83	35.47	64.13	65.62	64.88	45.28	45.52	45.39
M_2 : MW-25 (18-24 June)	28.62	29.01	29.08	34.57	35.01	34.96	63.18	64.89	64.04	45.01	45.02	45.01
M_3 : MW-26 (25 June-1 July)	25.90	26.48	26.19	30.91	31.48	31.19	60.80	60.96	60.88	41.13	41.84	41.48
S.Em ±	0.41	0.45	0.43	0.40	0.40	0.40	0.80	0.85	0.82	0.13	0.13	0.13
C.D. at 5 %	1.62	2.02	1.29	1.07	1.92	1.20	2.42	2.42	2.45	0.39	0.39	0.39
General Mean	27.84	28.43	28.22	33.53	34.10	33.78	62.70	63.82	63.26	43.80	44.12	43.96

Table 3: Protein and oil content in soybean as influenced by different treatments

Treatments	Protein content (%)			Oil content (%)			Protein yield (q ha^{-1})			Oil yield (q ha^{-1})		
	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean	2013	2014	Pooled mean
M_1 : MW-24 (11-17 June)	42.61	42.69	42.65	17.99	17.90	17.76	12.35	12.72	12.53	10.07	10.00	9.99
M_2 : MW-25 (18-24 June)	42.17	42.28	42.22	17.82	17.83	17.86	11.73	11.99	11.89	9.97	9.97	9.99
M_3 : MW-26 (25 June-1 July)	41.95	42.01	41.98	17.77	17.72	17.80	11.17	11.30	11.31	9.61	9.92	9.96
S.Em ±	0.28	0.29	0.28	0.24	0.20	0.22	0.16	0.17	0.16	0.04	0.04	0.04
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.48	0.57	0.49	0.12	0.17	0.12
General Mean	42.24	42.32	42.28	17.86	17.82	17.84	11.75	12.00	11.91	9.88	9.96	9.98

Table 4: Total nutrient uptake by soybean as influenced by different treatments

Treatments	Nutrient uptake (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	2013	2014	2013	2014	2013	2014
M_1 : MW-24 (11-17 June)	95.81	96.04	17.66	17.69	78.88	80.82
M_2 : MW-25 (18-24 June)	92.19	90.91	17.58	17.62	76.16	78.92
M_3 : MW-26 (25 June-1 July)	87.30	88.78	17.20	17.30	73.44	77.65
S.Em ±	1.27	1.70	0.28	0.27	0.97	0.95
C.D. at 5 %	3.62	5.13	0.84	0.81	2.72	1.90
General Mean	91.76	91.90	17.48	17.54	76.16	79.13

Table 5: Yield attributes of wheat as influenced by different treatments

Treatments	Panicle length (cm)		Panicle girth (cm)		Panicle wt. plant^{-1} (g)		Grain wt. panicle^{-1} (g)		1000 grain wt. (g)	
	2013-14	2014-15	2013-14	2014-15	2013- 14	2014-15	2013-14	2014-15	2013-14	2014-15
A. Meteorological week (*Kharif* soybean)										
M_1 : MW-24	6.88	7.77	3.27	4.02	2.63	3.33	2.07	2.70	41.31	42.50
M_2 : MW-25	6.56	7.54	3.04	3.74	2.32	2.88	1.98	2.50	39.79	42.04
M_3 : MW-26	6.02	7.22	2.81	3.02	2.04	2.42	1.72	2.21	38.27	41.23
S.Em ±	0.10	0.07	0.11	0.08	0.04	0.14	0.03	0.06	0.15	0.14
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B. Fertilizer levels (*Rabi* wheat)										
F_1 : 50 % of RDF	5.19	6.12	2.29	3.07	2.07	2.81	1.64	2.07	39.73	40.93
F_2 : 75 % of RDF	7.54	8.51	3.65	4.40	2.92	3.26	2.28	2.80	41.84	43.01
F_3 : 100 % RDF	8.10	9.08	3.82	4.54	3.01	3.61	2.40	3.01	42.53	43.66
S.Em ±	0.18	0.18	0.05	0.05	0.03	0.12	0.04	0.07	0.22	0.21
C.D. at 5 %	0.56	0.57	0.17	0.14	0.09	0.35	0.12	0.21	0.69	0.65
Interaction A x B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	6.71	7.70	3.14	3.79	2.49	3.05	2.01	2.54	40.57	42.22

* Sowing date of wheat 26 November.

Table 6: Grain and straw yield of wheat as influenced by different treatments

Treatments	Grain yield (q ha^{-1})		Pooled mean	Straw yield (q ha^{-1})		Pooled mean
	2013-14	2014-15		2013-14	2014-15	
A. Meteorological week (*Kharif* soybean)						
M_1 : MW-24	38.30	38.92	38.61	52.11	52.50	52.30
M_2 : MW-25	35.67	36.08	35.87	48.51	49.08	48.78
M_3 : MW-26	32.40	33.86	33.14	44.04	46.06	45.05
S.Em ±	0.74	1.07	0.91	0.62	0.47	0.55
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B. Fertilizer levels (*Rabi* wheat)						
F_1 : 50 % of RDF	35.16	35.36	35.26	47.68	48.08	47.88
F_2 : 75 % of RDF	37.68	38.14	37.91	51.24	51.87	51.55
F_3 : 100 % RDF	40.12	40.92	40.52	54.56	55.65	55.15
S.Em ±	0.80	0.88	0.84	1.08	1.09	1.08
C.D. at 5 %	2.48	2.78	2.60	3.34	3.35	3.34
Interaction A x B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	36.55	36.90	36.95	50.11	50.53	50.15

* Sowing date of wheat 26 November.

Table 7: Grain quality of wheat as influenced by different treatments

Treatments	Protein content (%)		Glutein content (%)	
	2013-14	2014-15	2013-14	2014-15
A. Meteorological week (*Kharif* soybean)				
M_1 : MW-24	9.55	9.72	4.11	4.07
M_2 : MW-25	9.12	9.64	3.96	4.04
M_3 : MW-26	9.01	9.59	3.91	4.01
S.Em ±	0.01	0.06	0.06	0.02
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.
B. Fertilizer levels (*Rabi* wheat)				
F_1 : 50 % of RDF	9.03	9.19	3.53	3.53
F_2 : 75 % of RDF	9.62	9.80	4.14	4.19
F_3 : 100 % RDF	9.85	9.95	4.30	4.41
S.Em ±	0.02	0.07	0.06	0.02
C.D. at 5 %	0.07	0.23	0.19	0.07
Interaction A x B	N.S.	N.S.	N.S.	N.S.
General mean	9.36	9.65	3.99	4.04

* Sowing date of wheat 26 November.

Table 8: Total nutrient uptake by wheat as influenced by different treatments

Treatments	Total nutrient uptake (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
A. Meteorological week (*Kharif* soybean)						
M_1 : MW-24	91.64	92.85	18.13	19.14	107.63	108.93
M_2 : MW-25	89.72	91.33	17.63	18.52	106.46	105.41
M_3 : MW-26	87.80	89.02	17.09	17.47	103.97	103.97
S.Em ±	0.45	0.54	0.13	0.17	0.30	1.36
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
B. Fertilizer levels (*Rabi* wheat)						
F_1 : 50 % of RDF	74.87	76.01	13.55	14.76	93.28	94.56
F_2 : 75 % of RDF	99.33	101.01	20.75	21.88	115.99	112.72
F_3 : 100 % RDF	100.54	102.13	21.45	22.59	117.10	116.54
S.Em ±	0.39	0.36	0.23	0.23	0.34	1.24
C.D. at 5 %	1.21	1.12	0.70	0.71	1.11	3.82
Interaction A x B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	91.58	93.05	18.58	19.74	108.79	107.94

* Sowing date of wheat 26 November.

Conclusion

Sowing in meteorological week 24 (11-17 June) to *kharif* soybean followed by 100 per cent recommended dose of fertilizer (120:60:40 kg N, P_2O_5 and K_2O ha^{-1}) to succeeding wheat crop during *rabi* season exhibited maximum growth, yield attributes and grain yield of wheat and it was identical to 75 per cent recommended dose of fertilizer (90:45:30 kg N, P_2O_5 and K_2O ha^{-1}) to wheat crop indicating 25 per cent saving of fertilizer to wheat crop in soybean-wheat cropping system and also 100 per cent recommended dose of fertilizer (120:60:40 kg N, P_2O_5 and K_2O ha^{-1}) to succeeding wheat during *rabi* season found superior by recording higher protein and glutein content in wheat grain.

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