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Productivity and Profitability of Cotton-wheat Cropping System as Influenced by Complex Fertilizers

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Authors' contributions

This work was carried out in collaboration among all authors. Author BSB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GSD and FSS managed the analyses of the study. Author FSS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted during 2012-13 and 2013-14 at Ludhiana, Punjab to find out the productivity and profitability of the cotton-wheat cropping system as influenced by complex fertilizers. The experiment was comprised of nine fertilizer treatments. The results demonstrated that significantly higher cotton yield and stalk yield was recorded under T_9 -AP60+S15+Zn1.5 (15.3 q/ha and 50.5 q/ha respectively in 2012 and 22.2 q/ha and 55.6 respectively in 2013) which was statistically at par with T_6 – DAP (P60)+S15+Zn1.5 (15.0 q/ ha and 50.4 q/ha respectively in 2012 and 22.1 q/ha and 55.4 q/ha, respectively in 2013). Similarly in wheat crop, T_9 -AP60+S15+Zn1.5 gave significantly higher grain yield and straw yield (39.0 q/ha and 63.0 q/ha, respectively in 2012-13 and 45.6 q/ha and 73.6, respectively in 2013-14) which was comparable with T_6 – DAP (P60)+S15+Zn1.5 (38.5 q/ ha and 62.8 q/ha respectively in 2012-13 and 44.4 q/ha and 72.4 q/ha in 2013-14) as compare to other treatments. Economic analysis indicated higher net return (≠ 8739.0) and B:C ratio (0.37) for cotton under T_8- AP30+S7.5+Zn0.75 whereas T_9 -AP60+S15+Zn1.5 net return (≠14417.5) and B:C ratio (1.07) for wheat as compare with other treatments.

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1. INTRODUCTION

Phosphorous (P), Sulphur (S) and Zinc (Zn) have been recognized as the most important essential plant nutrients next to N and K required for optimum plant growth [1]. Improper supply of these nutrients leads to a considerable reduction in crop productivity of crops. Majority of the Punjab's soils are medium to high in P, S and Zn [2]. The efficiency of applied P rarely exceeds 30 per cent and that of micronutrient more than 10 per cent. Therefore, repeated application of P over the years, lead to its build up and interactions in soil and/or plants affecting agricultural production. Sulphur is removed by crops in large quantities owing to its indispensable role in plant nutrition. It plays a great role in sustaining growth, yield and quality of crops, particularly pulses and oilseeds. Moreover, continuous use of DAP as P source instead of single super phosphate has led to S nutrition problems in the Indian soils and crops.

Continuous removal of S by crops, use of S free fertilizers and low S status of most of the Indian soils are major constraints in S nutrition management. Moreover, deficiency of one nutrient undoubtedly will reduce the efficiency of the other nutrient applied. Hence, it may be worthwhile to apply S and P together, which may boost up the use efficiency of both due to positive and synergistic interaction between the two elements.

Zinc is removed by crops in large quantities owing to its indispensable role in plant nutrition. It plays an important role in sustaining yield and quality of crops. The need for applying micronutrient fertilizers to soils of Punjab was first felt with the appearance of Zn deficiency in rice and wheat. The adoption of intensive agriculture in irrigated areas involving the cultivation of high yielding crop varieties, use of high analysis micronutrient fertilizers, decreased use of organic manures and crop residues, resulted in depletion of finite micronutrients reserves due to bumper harvests. The deficiency of Zn is mainly associated with soil having coarse texture, high pH, low organic carbon and high calcium carbonate (Takkar, et al. 1999). Zinc plays an important role in plant metabolisms like development of cell wall, respiration, photosynthesis, chlorophyll formation, enzyme activity and other bio-chemical functions. Amongst all the micronutrients Zn deficiency continues to be one of the critical factors in determining crop production. Crops utilize only a small quantity of the applied Zn for their healthy growth. The considerable amount of Zn remains in the soil, which can be utilized by the subsequent crops. For sustaining high productivity and increasing the efficiency of applied Zn fertilizers, it is essential to determine the frequency of its application under different cropping systems. Hence, it may be worthwhile to apply P, S and Zn together, which may boost up the use efficiency of these elements.

2. MATERIALS AND METHODS

The experiments were conducted at Research Farm, Department of Soil Science, Punjab Agricultural University (PAU), Ludhiana, Punjab, India. Ludhiana is situated at 30º56' N and 75º52' E at 247 m above sea level. This region belongs to C_4 climate zone characterized by hot air conditions. The soils at PAU Farm were classified as coarse loamy, non-calcareous, typic *Ustochrepts.*

The surface soil samples were collected, oven dried and sieved for to determine the status of N (Subbiah and Asija 1956), P (Olsen, et al. 1954), and K (Merwin and Peech 1950) using kjeldhal, colorimeter and flame photometer, respectively. Available S (0.15% $CaCl_2$ extractable) and DTPA-Extractable Zn was detected using the method described by Lindsay and Norvell (1978). The initial fertility status of experimental soils during both years is represented in Table 1. These soils were normal in soil reaction and salt concentration, low in available N and K, medium in available P, sufficient in available S and DTPA-Zn.

The cotton and wheat crops were raised as per agronomic practices recommended under irrigated condition by Punjab Agricultural University, Ludhiana [3,4]. The full dose of P and K was applied at the time of sowing of cotton and wheat. In cotton half of the recommended N was applied at the time of thinning and remaining half of N was broadcasted at the time of flowering. In wheat half of the recommended N was applied at the time of sowing and remaining half of N was broadcasted at the time of 1st irrigation. The basic detail of experiments conducted is presented in Table 2.

Nine combinations of nutrient was arranged in a randomized block design and replicated thrice.

Table 1. Nutrient status and chemical parameters of experimental soils

Site	pH	EC dSm^{-1}	OC (%)	Avail. N	Avail. P	Avail. K	Avail. S	Avail. Zn
				($kg\ ha^{-1}$)				ppm
Cotton-wheat (2012-13)	7.5	0.07	0.31	83.2	10.8	71.0	12	1.48
Cotton-wheat (2013-14)	7.5	0.14	0.33	86.3	13.4	85.0	9.2	1.55

Table 2. Basic details of the experiments conducted during 2012-14

Crop	Cotton		Wheat	
	2012	2013	2012-13	2013-14
Variety	Ankur 3028	Ankur 3028	PBW 621	PBW 621
Date of sowing	28 April	30 April	19 Dec.	14 Nov.
Date of harvesting/ picking	18 October, 7 Nov., 23 Nov.	7 Sept., 8 October, 5 Nov.	20 April	20 April

Table 3. Details of experimental treatments

	Nutrient source	Cotton			Wheat		
		P (P_2O_5)	S	Zn	P (P_2O_5)	S	Zn
		$kg\ ha^{-1}$					
T_1	Control (N+ K)	0	0	0	0	0	0
T_2	DAP(P30)	30	0	0	30	0	0
T_3	DAP(P30)+S7.5	30	7.5	0	30	7.5	0
T_4	DAP(P20)+S5+Zn0.5	20	5.0	0.50	20	5.0	0.50
T_5	DAP(P30)+S7.5+Zn0.75	30	7.5	0.75	30	7.5	0.75
T_6	DAP(P60)+S15+Zn1.5	60	15.0	1.50	60	15.0	1.50
T_7	AP20+S5+Zn0.5	20	5.0	0.50	20	5.0	0.50
T_8	AP30+S7.5+Zn0.75	30	7.5	0.75	30	7.5	0.75
T_9	AP60+S15+Zn1.5	60	15.0	1.50	60	15.0	1.50

The performance of complex fertilizer was compared with equivalent amount of conventional fertilizer sources of P (DAP), S (gypsum) and Zn ($ZnSO_4$). The details of experimental treatments are presented in Table 3. Nitrogen applied through APSZ (ammonium phosphate containing S and Zn complex fertilizer N12:P40:K0:S10:Zn1) and DAP (Diamminium phosphate) was compensated with urea. The source of N and K was urea and muriate of potash, respectively. Source of P was DAP and APSZ. S was applied through gypsum and APSZ. Source of Zn was zinc sulphate ($ZnSO_4.7H_2O$) or APSZ.

Data pertaining to yield and yield attributes were collected at the time of crop harvest. The data collected from the experiment was subjected to statistical test by following 'Analysis of variance technique'. Year wise data were analysis using SPSS software. The critical difference (CD) values at 5% level of probability were computed for making comparison between treatments.

3. RESULTS AND DISCUSSION

3.1 Effect on Cotton Yield and Stalk Yield

The cotton and stalk yield significantly improved with P application as compared to control irrespective of sources and level of their application (Table 4). The response of cotton to P was observed because the experiment was started from cotton and the P was not applied to the previous crop in *rabi* season. The status of P of the experimental soil was medium. The cotton yield was significantly increased with the application of P either through DAP or APSZn (complex fertilizer) as compared to control irrespective to its level of application during 2012. There was significant increase in cotton yield under T_5 and T_8 (P_2O_5 at 30 kg ha^{-1} as compared to T_4 and T_7 (P_2O_5 at 20 kg ha^{-1}) irrespective of its source of application. However, the effect between P_2O_5 at 30 kg ha^{-1} (T_2, T_3, T_5 and T_8) and P_2O_5 at 60 kg ha^{-1} (T_6, T_8 and T_9) was non-significant. This indicates that the P applied through complex and DAP fertilizer has equal effect on cotton yield. There was non-significance improvement in cotton yield with the application of S (T_2 and T_3). The non-significant difference between T_3 and T_5 indicated no response to Zn application. The effect of S and Zn application was non-significant on yield of cotton. This may be due to the reason that experimental soil contain sufficient amount of available S (>10 ppm) and DTPA-Zn (>0.6 mg kg^{-1}). Similar trends were also observed for stalk yield of cotton. The cotton yield in 2013 was significantly increased with the application of P either through DAP or APSZn (complex fertilizer) as compared to control irrespective to its level of application.

There was significant increase in cotton yield in T_5 (21.7 q ha^{-1}) and T_8 (22.0 q ha^{-1}) as compared to T_4 (17.2 q ha^{-1}) and T_7 (17.4 q ha^{-1}), irrespective of its source of application during 2013. However, the higher amount of P (P_2O_5 at 60 kg ha^{-1}) had non-significant effects on yield when compared with (P_2O_5 at 30 kg ha^{-1}). This indicates that the P applied through complex and DAP fertilizer has equal effect on cotton yield. Cotton yield increases significantly with application of 7.5 kg S ha^{-1}during 2013 because soil was deficient in S. However, the response of S application was not significant during 2012 due to medium status of soil. Application of Zn along with P and S did not result in improvement of cotton yield during both the year because soil was not deficient in Zn. Similar trend was also observed for stalk yield of cotton. Gobi and Vaiyapuri [5] found similar results that with the application of 45 kg S + 10 kg Zn + 1kg B per ha increases the yield of cotton. Similarly, Ali, et al. [6] noted that Zn and B at 0.75+1.00 kg as foliar spray found to be best fertilizer for higher seed cotton yield.

3.2 Effect on Grain and Straw Yield of Wheat

The data pertaining to effect of different sources and level of P, S and Zn fertilizer on wheat yield during 2012-13 and 2013-14 are presented in Table 5. During 2012-13 the minimum (29.0 q ha^{-1}) and maximum (39.0 q ha^{-1}) grain yield was recorded under T_1 and T_9 treatment. The significant response to P application was observed from the plots which received P_2O_5 at 20 kg ha^{-1} (T_4 and T_7), P_2O_5 at 30 kg ha^{-1} (T_3, T_5 and T_8) and P_2O_5 at 60 kg ha^{-1} (T_6 and T_9) as improved grain yield of wheat irrespective of sources of their application. The effect of S and Zn application applied through different sources did not affect wheat grain yield. The lowest and highest straw yield was recorded under T_1 (control) and T_9 treatment. The straw yield under complex fertilizer (T_7, T_8 and T_9) was at par with the straw yield of wheat under equivalent amount of other fertilizers (T_4, T_5 and T_6), indicating that the availability of nutrient with the source was same. The minimum (30.2 q ha^{-1}) and maximum (45.6 q ha^{-1}) grain wheat yield during 2013-14 was recorded under T_1 and T_9 treatment respectively. The application of P_2O_5 at 30 kg ha^{-1} in T_3 (37.3 q ha^{-1}), T_5 (37.8 q ha^{-1}) and T_8 (38.2 q ha^{-1}) and P_2O_5 at 60 kg ha^{-1} in T_6 (44.4 q ha^{-1}) and T_9 (45.6 q ha^{-1}) significantly improved the grain yield of wheat as compared to the plot received P_2O_5 at 20 kg ha^{-1} in T_2 (34.2 q ha^{-1}) and T_7 (35.9 q ha^{-1}) and T_1 (30.2 q ha^{-1}) irrespective of sources of their application. There was significant difference between the yield of plot received P_2O_5 at 60 kg ha^{-1} and P_2O_5 at 30 kg ha^{-1} and this effect was similar for both DAP and complex fertilizer. The effect of P, S and Zn applied through complex fertilizer on grain yield was not significantly higher than the equivalent amount of P, S and Zn applied through DAP, gypsum and $ZnSO_4$ fertilizers, respectively. The lowest and highest straw yield was recorded under T_1 (control) and T_9 treatment. The straw yield under complex fertilizer (T_7, T_8 and T_9) was at par with the straw yield of wheat under equivalent amount of other fertilizers (T_4, T_5 and T_6), indicating that the availability of nutrient with different source was same. Gupta, et al. [7] reported that S application significantly enhanced wheat yield and yield components. Similarly Yilmaz, et al. [8] found that application of Zn irrespective of method of application increase grain yield as compared to control. Similar results were found by Shukla and Warsi [9] that application of Zn, S and Mn increased grain yield of wheat as compare to control.

3.3 Plant Parameters of Wheat as Affected by Levels of Sources of P, S and Zn Fertilizers

The data pertaining to effect of levels and sources of P, S and Zn fertilizers on ear length, tiller per square meter and plant height of wheat (PBW 373) during 2012-13 are presented in the Table 6. There was significant improvement in ear length under T_2, T_3, T_5, T_6, T_8 and T_9 with the application of P, S, and Zn through different fertilizers as compared to control. The minimum and maximum ear length was recorded under treatment T_1 (7.7 cm) and T_9 (9.4 cm) respectively. The improvement in ear length under T_6 and T_9 (P_2O_5 at 60 kg ha^{-1}) was significant compare to the source of nutrients received P_2O_5 at 20 kg ha^{-1}. The application of P, S and Zn fertilizer significantly improved number of tiller per square meter except T_4 and T_7 source of nutrients. The results clearly indicate that the ear length and number of tillers in wheat increases with application of P from both the sources. However the effect of S application along with P and Zn along with P and S was non-significant. There was improvement in plant height with the application of P, S and Zn fertilizer as compared to control. However, the effect was significant only for T_6 and T_9 source of nutrients. There was significant improvement in ear length under fertilized treatments with the application of P, S, and Zn through different fertilizers as compared to control during 2013-14. The minimum and maximum ear length was recorded under treatment T_1 (9.7 cm) and T_9 (10.9 cm). The ear length under T_1 was significantly lower than other source of nutrients. The application of P, S and Zn fertilizer significantly improved number of tiller per square meter as compared to control having maximum number of tillers under T_6 and T_9 source of nutrients. The results clearly indicate that the ear length and number of tillers in wheat increased with application of P from both the sources. There was improvement in plant height with the application of P, S and Zn fertilizer as compared to control. Tillering, plant height, spike length, number of grain spike-1, 1000 grain weight, straw and grain yield were statistically significant in treatment 50 kg S ha-1 as compare to 25 and 75 kg S ha-1. Ali, et al. [10] Malle, et al. [11] finding also revealed that with application of S improved grain yield and yield attributes of wheat. In another study, application of Zn, S and Mn increased the growth characters (LAI, LAR, NAR, RGR and dry matter accumulation) and grain yield of wheat as compare to control [8].

Table 4. Effect of different sources of P, S and Zn fertilizer on cotton productivity

Nutrient source		Cotton yield (q ha^{-1})		Stalk yield (q ha^{-1})	
		2012	**2013**	**2012**	**2013**
T_1	Control (N+ K)	10.9 a	15.9 a	43.0 a	45.5 a
T_2	DAP(P30)	14.2 c	19.4 c	47.9 bc	48.4 ab
T_3	DAP(P30)+S7.5	14.3 c	19.6 c	48.2 bc	49.1 b
T_4	DAP(P20)+S5+Zn0.5	12.4 b	17.2 b	45.9 b	46.7 ab
T_5	DAP(P30)+S7.5+Zn0.75	14.7 c	21.7 d	48.7 bc	54.3 c
T_6	DAP(P60)+S15+Zn1.5	15.0 c	22.1 d	50.4 c	55.4 c
T_7	AP20+S5+Zn0.5	12.3 b	17.4 b	45.9 b	47.5 ab
T_8	AP30+S7.5+Zn0.75	14.8 c	22.0 d	48.4 bc	54.9 c
T_9	AP60+S15+Zn1.5	15.3 c	22.2 d	50.5 c	55.6 c

**Values within a column, followed by different letters are significantly different at p<0.05 by Duncan's multiple range tests*

Table 5. Effect of different levels and sources of P, S and Zn fertilizers on grain and straw yield of wheat

Nutrient source		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
		2012-13	**2013-14**	**2012-13**	**2013-14**
T_1	Control (N+ K)	29.0 a	30.2 a	42.0 a	42.3 a
T_2	DAP(P30)	35.3 b	34.2 b	52.3 b	50.6 bc
T_3	DAP(P30)+S7.5	35.5 b	37.3 c	52.8 b	55.5 cde
T_4	DAP(P20)+S5+Zn0.5	30.7 a	34.8 bc	42.8 a	48.5 b
T_5	DAP(P30)+S7.5+Zn0.75	35.5 b	37.8 c	53.0 b	56.4 de
T_6	DAP(P60)+S15+Zn1.5	38.5 c	44.4 d	62.8 c	72.4 f
T_7	AP20+S5+Zn0.5	30.8 a	35.9 b	43.8 a	51.0 bcd
T_8	AP30+S7.5+Zn0.75	35.8 b	38.2 c	53.3 b	56.9 e
T_9	AP60+S15+Zn1.5	39.0 c	45.6 d	63.0. c	73.6 f

**Values within a column, followed by different letters are significantly different at p<0.05 by Duncan's multiple range tests*

Table 6. Plant parameters of wheat as affected by levels and sources of P, S and Zn fertilizers

Nutrient source		Ear length (cm)		Tiller m^{-2}		Plant height (cm)	
		2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
T_1	Control (N+ K)	7.7 a	9.7 a	164.4 a	200 a	73.5 a	85.9 a
T_2	DAP(P30)	8.6 bc	10.5 b	181.7 bc	205 b	77.3 ab	87.6 ab
T_3	DAP(P30)+S7.5	8.7 bc	10.5 b	182.3 bc	209 c	76.5 ab	87.4 ab
T_4	DAP(P20)+S5+Zn0.5	8.3 ab	9.9 a	171.7 ab	205 b	78.1 ab	86.8 ab
T_5	DAP(P30)+S7.5+Zn0.75	9.0 bc	10.6 bc	186.0 cd	220 d	78.7 ab	88.1 bc
T_6	DAP(P60)+S15+Zn1.5	9.3 c	10.9 c	196.1 d	222 e	80.9 b	89.9 d
T_7	AP20+S5+Zn0.5	8.4 ab	9.9 a	172.2 ab	204 b	78.5 ab	86.6 ab
T_8	AP30+S7.5+Zn0.75	9.1 bc	10.6 bc	187.2 cd	221 e	79.7 ab	89.7 cd
T_9	AP60+S15+Zn1.5	9.4 c	10.9 c	197.1 d	222 e	81.1 b	90.8 d

**Values within a column, followed by different letters are significantly different at p<0.05 by Duncan's multiple range tests*

Table 7. Enterprise budget of cotton and wheat crops under cotton-wheat rotation, Rs per acre

Nutrient source		Cotton			Wheat		
		Cost	Net Return	BCR	Cost	Net Return	BCR
T1	Control (N+ K)	23,134.8	874.2	0.04	12,600.5	7,769.0	0.62
T2	DAP(P30)	23,754.8	5,965.0	0.25	13,271.5	10,819.0	0.82
T3	DAP(P30)+S7.5	23,929.8	6,059.0	0.25	13,458.5	11,799.0	0.88
T4	DAP(P20)+S5+Zn0.5	23,437.8	2,945.8	0.13	13,186.5	9,262.0	0.70
T5	DAP(P30)+S7.5+Zn0.75	23,952.8	8,209.2	0.34	13,481.5	11,965.5	0.89
T6	DAP(P60)+S15+Zn1.5	24,824.8	7,977.0	0.32	14,417.5	14,878.5	1.03
T7	AP20+S5+Zn0.5	23,529.8	2,955.6	0.13	13,186.5	9,755.5	0.74
T8	AP30+S7.5+Zn0.75	23,754.8	8,739.0	0.37	13,481.5	12,197.5	0.90
T9	AP60+S15+Zn1.5	24,429.8	8,703.8	0.36	14,417.5	15,417.5	1.07

4. ECONOMICS

Net return and B: C ratio for cotton were higher under T8 (AP30+S7.5+Zn0.75) in cotton crop as compare to other nutrients sources. This could be due to less labour required for application of fertilizer. On the other hand, a significant high yield and maximum B: C ratio for wheat was recoreded under T9 (AP60+S15+Zn1.5) as compared to other nutrients sources. Similar study was done by Gobi and Vaiyapuri [5] where higher net return per rupee invested

5. CONCLUSION

In the present study, cotton-wheat cropping system responded for the application P fertilizer. The effect of conventional fertilizer of P (DAP) and complex fertilizer (APSZn) on crop productivity was statistically similar. Management of P through APSZn in cotton-wheat cropping system was more profitable compared to P application through DAP.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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