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RESEARCH ARTICLE

WHEAT YIELD RESPONSE TO POTASSIUM SULFATE SUPPLEMENTAL DOSES IN URBAN AGRICULTURE OF KABUL, AFGHANISTAN

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ABSTRACT

Wheat, strategic crop of Afghanistan is cultivated in irrigated and non-irrigated land surfaces. Insufficient rainfalls trigger the intensification of wheat cultivation in irrigated areas. Indiscriminate use of irrigated land depletes crop essential nutrients which lead to soil potassium (K^+) mining. A research has been conducted (2012 – 2013) to evaluate the supplemental effect of three levels (25; 35 and 45 kg ha^{-1}) of potassium sulfate (PS, K_2SO_4) with a basal dose of 250 kg urea ha^{-1} and 125 kg diammonium phosphate (DAP) ha^{-1}, on wheat yield in Urban Agriculture (UA) of Kabul. The wheat (*winter var.Gul 96*) was cultivated in two seasons. Randomized complete block design (RCBD) was used. Four treatments were replicated four times and were irrigated upon the requirement. The parameters; *plant height*; *number of productive tiller/plant*; *number of spikelet/spike*, *Spike length*, *thousand grain weight*, and *total grain yield* were measured. The results showed that wheat *var. Gul 96* is a facultative variety. The plant heights in 25, 35 and 45 kg PS ha^{-1} were greater (25.60, 25.12 and 24.90%) than control (24.38%), respectively. Plant heights in fall cultivation (FC) were higher (54%) than spring cultivation (SP, 46%). Numbers of productive tillers per plant were greater (26.44%) in both seasons in 25 kg PS ha^{-1} than control (26.27%), whilst, in 35 and 45 kg PS ha^{-1} were (23.03 and 24.26%), less than control, respectively. Numbers of spikelet per spike was higher in 25 and 45 kg PS ha^{-1} (25.26%) than control (24.97%), whereas, plot of 35 kg PS ha^{-1} had less (24.52%) than control. Thousand grain weights were greater in 25, 35, and 45 kg PS ha^{-1} in both seasons by 25.40, 25.16 and 24.98 % than control (24.52%), respectively. Total grain yield in both seasons in 25 and 45 kg PS ha^{-1}, were greater (27.89 and 26.40%) than control (23.86%), respectively, while, plot of 35 kg PS ha^{-1} had less (21.86%) than control. Statistically the differences were highly significant ($P< 0.05$).

INTRODUCTION

Kabul city with 4.2 million populations is located in continental climatic zone (CSO, 2015). The city's built-up areas surrounds by urban farms which usually have been used for vegetable, forage and Cereal productions. Among cereals, wheat is the main food grain for urban citizens which are cultivated in the rotation for self use. Nevertheless, every adult in Afghanistan consume 160-180 kg of wheat per annum (FAO, 2003). This required improvement of wheat yield or supplementation of food from abroad. Alike the destruction of other infrastructures, three decades of war and conflict in Kabul reduced wheat production and destroyed crop research centers across the country. Lack of information in soil crop analysis, fertilizers application and mismanagement of endemic input sources reduce soil productivity.

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Additionally, Fertilizer manufacturer companies are non-functional which lead to procure fertilizers from foreign countries with disproportionate prices. However, there is need to increase food against 3.5% annual population growth. Kabul urban farmers are obliged to use local materials such as urban wastes, sewages and other city bio-solids to improve wheat and other crop production (Safi *et al*. 2011). Earlier, Mazar-e-Sharif Fertilizer Company recommended 21 kg DAP ha^{-1} and 35 kg urea ha^{-1} for fall cultivation and 28 kg DAP ha^{-1} and 28 kg urea ha^{-1} for spring cultivation. The company also suggests that high amount of fertilizers application may be efficiently used by improved varieties vs local varieties. Though, 50 kg urea ha^{-1} has also been recommended for improving wheat yield in Afghanistan (Samin, 2008). Recently, the suggested amount of urea application with supplemental dose of 25 kg DAP $ha^{-1}$was observed in the field of farmers' prior to seeding (Safi, *et al*., 2011). Records from Kabul and all over the country showed that only nitrogen (N) and phosphorus (P) fertilizers cannot improve wheat yield.

However, complete and balanced fertilization may improve wheat yield which was revealed by a survey of 112 farms in five province, that application of complete fertilizer (120 kg N:120 kg P:120 kg K ha^{-1}) improved wheat yield by 4 tons ha^{-1} (Alam, *et al*. 2009; Samin, 1981). At present wheat farms in Kabul, in spite of enough N and P fertilizers in association with city bio-wastes' and animal manure application, is not responding satisfactory in to improvement in wheat yield. Possible explanation seems to be lack of K in these soils, because during spring season plant's available K may be leached out from sandy or medium soils with overloaded rain water and be removed by fresh vegetable. The attraction between potassium ions with sandy soil and soil organic matter particles is relatively weak and lead to the K leaching from both type of soils, where these soils require precise annual K application, since it is not possible to build up high K reserves (Schulte and Kelling, 2016). However, amending soil with animal manure can improve K contents but keeping small number of animals in the households' farm cannot provide enough animal manure for their farms.

A study has been conducted to examine initially the effect of three levels of PS on yield of wheat in association with Nitrogen (N) and Phosphorus (P) fertilizers. The third major nutrient K, which is one of the essential macronutrients required by all plants and is present in plant in form of cation K^+. K plays significant role in many metabolic and biologic processes, such as photosynthesis, carbohydrate relocation, plant water regulation, and protein synthesis. Moreover, availability of adequate quantity of K helps plants to tolerate unfavorable conditions like drought, frosts, and soil salinity. Similarly, in the presence of adequate amount of K, plants resist well against pests and diseases (Brady and Weil, 2015; Kumar. 2015; Bharat Singh. 2016; Singh, 2014). Prominently, K is not an environmental pollutant (Hodges, 2012; Baque, *et al*. 2006). Furthermore, adding K can improve saline soils conditions in the favor of many plants (Hussain *et al*., 2013). A study in Nangarhar and Laghman provinces of Afghanistan revealed that application of K fertilizers improved wheat yield significantly (Samin, 1997). However, there are different types of K fertilizers that are commonly used for wheat yield improvement across the world. In this study we were trying to apply readily available K fertilizer to examine its effects on wheat yield improvement. So, we chose PS, providing K simultaneously with sulfur (S) which is also part of essential macronutrients for plants as well.

Farmers' problems across Kabul city are 1) applying adequate amount of N (250 kg ha^{-1}) and P (125 kg-ha^{-1}) fertilizers, and organic fertilizer (animal manure, City bio-wastes and etc.,5-15 MT ha^{-1}), but wheat yield is not responding well or not improved., 2) Despite of application of sufficient amount of N, P and organic fertilizers, wheat crops are weak, small and cannot resist drought, pests and diseases. Possibly, these symptoms display deficiency of K which enhances plant rigidity. 3) Presence of adequate amounts of N and P, and reduced amount of K lead to imbalance crop essential nutrient concentrations. Presence of high concentration of calcium carbonate (8-11%) can negatively affect K availability for plants and also the dominated rotation of vegetable crops may eliminate high amount of K from urban farms (Safi *et al*., 2011)., 4) K shortage is evidenced in vegetables and fruits in Kabul Urban Farms.

Thus, this reveals that reduced wheat yield may be led by K deficiency. The objectives of this study were to: 1) examine the effect of three levels of PS on wheat yield improvement; 2) recognize the cultivation season (spring or fall) of wheat, *var.Gul 96,* 3) examine the effect of PS on wheat, *var.Gul 96* in both seasons (spring and fall); 4) find a suitable supplemental dose of PS for Kabul agro-ecosystem; and 5) improve wheat yield in UA of Kabul.

MATERIALS AND METHODS

Site Description

The study site is located at Kabul University, Agriculture Faculty Farm (Lat. 34º29'59.76" N, 69º09'22.06" E, 1800 m.a.s.l.) Kabul, Afghanistan. The mean annual precipitation is estimated 300-330 mm and the average annual temperature is 10-13ºC. The average humidity was estimated about 54% between 1957-1977 (Grieser *et al*. 2006; Houben and Tunnermeier, 2005). Soils of the study site had 9.3% calcium carbonate, 4 to 5 % organic matter and plant available K is ranging from 0.2 to 0.5 g kg^{-1} between spring 2008 to fall 2009 (Safi, *et al*. 2011) However, the study site cannot represent all urban farms across Kabul city but the soils, fields' slope and inputs application were identical.

Experimental layout

Randomized Complete Block Design (RCBD) was used. Treatments were four and have been replicated four times. Size of every plot was 4 m^2 (2m x 2m). Seed rate (175 kg ha^{-1}) was according to the local farmers' seed rate having been practiced. Supplemental dose of PS (25, 35, 45 kg ha^{-1} and a plot of control with 0 kg PS ha^{-1} in association with a basal dose of 250 kg urea ha^{-1} and 125 kg DAP ha^{-1} were used.

Measurements

Pure seeds of wheat, (*var.Gul 96*) was weighed and then cultivated at both fall and spring seasons. The following parameters were measured: Plant height: Ten plants were randomly selected in each plot, their heights were measured and averaged heights were recorded. Number of Productive tiller: Ten plants were randomly selected in each plot, mean number of productive tillers were recorded. Spike Length: Ten plants were randomly selected, measured and the averaged spike lengths were recorded. Number of Spikelet per spike: Ten plants were randomly taken from each plot and numbers of spikelet per spike were counted, mean numbers of spikelets per spikes were recorded. Thousand grain weight: Five-bushel seeds were randomly taken from each plot, and 1000 seeds were weighed from each bushel, the average weight of 1000 seeds was recorded. Total grain weight: Total grain in each plot was weighed and converted to hectare basis as well.

Data Analysis

All data were analyzed using the General Linear Model (PROC GLM) in SPSS (Version 18.0, SPSS Inc., Chicago, IL, USA) atα = 0.05. Effects of various level of PS on wheat were analyzed separately for each variable. When significant effects were detected between main effects, Least Significant Difference (LSD) test was performed to detect differences

between treatment means at $P = 0.05$. Residuals for all response variables were checked for normality and constant variance based on ANOVA assumptions.

RESULTS

Plant height

Effects of different amounts of PS on plant height in SC 2012 and FC 2013 of wheat *var. Gul 96* are compared (Table 1). Our results showed that in control, 25, 35 and 45 kg PS ha^{-1} treatments, SC plants height (47, 45, and 47 %) was less than that in FC, (53%), respectively. Total plant height (n=8) in control treatment (24.38%) was less than that in 25, 35 and 45 kg PS ha^{-1} treatments (25.60, 25.12 and 24.90 %), respectively. Collectively in both years (n=16), plant height in SC (46%) was less than that in FC period (53%). All these differences were significant at ($P< 0.05$).

Together in both (n= 8) SC and FC periods, number of productive tiller per plant in control was (26.44 %) less than that in 25 kg PS ha^{-1}. while, it was higher in control compared to 35 (23.03%) and 45 (26.24%) kg PS ha^{-1}. Collectively in both years (n=16), number of productive tillers per plant was higher in FC (54%) compared to SC period (46%). The differences were significant at ($P< 0.05$).

Spike length

Effects of different amounts of PS on spike length in SC, 2012 an FC, 2013 of wheat *var.Gul 96* are compared (Table 3). Among all treatments, spike length was greater in FC (57, 58, 58 and 57 %) compared to SC (43, 42, 42 and 43 %), respectively. Together, in both SC and FC periods (n=8), length of spike was smaller in control (24.27 %) compared to fertilized (25, 35 and 45 kg PS ha^{-1}) ones (25.26, 24.65 and 25.37 %), respectively. Collectively in both years (n=16),

Table 1. Effect of three level of PS on wheat plant height in both SC and FC periods

Parameter	Treatment (kg ha^{-1})	Year	Mean	SD	n
Wheat plant height (cm)	0 K_2SO_4	2012	88.50	2.65	4
		2013	77.83	3.96	4
		Total	73.16	5.88	8
	25 K_2SO_4	2012	72.00	2.94	4
		2013	81.65	2.62	4
		Total	76.83	5.77	8
	35 K_2SO_4	2012	68.50	5.45	4
		2013	82.23	3.18	4
		Total	75.36	8.42	8
	45 K_2SO_4	2012	69.50	9.15	4
		2013	79.90	3.97	4
		Total	74.70	8.57	8
	Total	2012	69.63	5.29	16
		2013	80.40	3.58	16
		Total	75.01	7.05	32

(P = <0.05)

Table 2. Table 1. Effect of three level of PS on number of productive tillers per plant in SC and FC periods

Parameter	Treatment (kg ha^{-1})	Year	Mean	SD	n
Number of productive tiller per plant (count)	0 K_2SO_4	2012	5.75	1.50	4
		2013	8.34	1.46	4
		Total	7.04	1.95	8
	25 K_2SO_4	2012	6.75	0.96	4
		2013	7.43	0.68	4
		Total	7.09	0.85	8
	35 K_2SO_4	2012	5.50	0.58	4
		2013	6.85	0.87	4
		Total	6.18	0.99	8
	45 K_2SO_4	2012	6.50	1.29	4
		2013	6.51	0.39	4
		Total	6.51	0.88	8
	Total	2012	6.13	1.15	16
		2013	7.28	1.10	16
		Total	6.70	1.25	32

(P = <0.05)

Number of productive tiller per plant

Effects of different amounts of PS on number of productive tiller per plant in SC, 2012 and FC, 2013 of wheat *var. Gul 96* was compared (Table 2). In control, 25, 35 and 45 kg PS ha^{-1} treatments number of productive tiller per plant was higher (59, 52, 55, 50.04, %) in FC than that in SC plants (41, 48, 45 and 49.96%), respectively.

spike length was greater in FC (57%) than that of SC (43%) period. All these differences were significant at ($P< 0.05$).

Number of spikelet per spike

Effect of different amounts of PS on number of spikelet per spike in SC and FC wheat *var.Gul 96* are compared (Table 4).

Table 4. Effects of three level of PS on number of spikelet per spike in both SC (2012) and FC (2013) periods

Parameter	Treatment (kg ha^{-1})	Year	Mean	SD	n
Number of spikelet per spike (count)	0 K_2SO_4	2012	15.25	0.50	4
		2013	20.67	0.96	4
		Total	17.96	2.98	8
	25 K_2SO_4	2012	15.00	1.41	4
		2013	21.65	1.60	4
		Total	18.32	3.81	8
	35 K_2SO_4	2012	14.00	1.63	4
		2013	20.67	0.89	4
		Total	17.33	3.77	8
	45 K_2SO_4	2012	15.50	1.91	4
		2013	21.12	1.10	4
		Total	18.31	3.33	8
	Total	2012	14.93	1.43	16
		2013	21.03	1.13	16
		Total	17.98	3.34	32

(P = <0.05)

Table 5. Effect of three level of PS on weight of thousand grains in both SC (2012) and FC (2013) periods

Parameter	Treatment (kg ha^{-1})	Year	Mean	SD	n
Thousand grain Weight (gr)	0 K_2SO_4	2012	39.50	3.00	4
		2013	31.34	4.46	4
		Total	35.42	5.61	8
	25 K_2SO_4	2012	39.50	1.00	4
		2013	33.86	2.00	4
		Total	36.68	3.35	8
	35 K_2SO_4	2012	38.50	1.91	4
		2013	34.17	2.26	4
		Total	36.33	3.02	8
	45 K_2SO_4	2012	36.00	3.65	4
		2013	35.99	2.37	4
		Total	35.99	2.85	8
	Total	2012	38.38	2.75	16
		2013	33.84	3.14	16
		Total	36.11	3.71	32

(P = <0.05)

Table 5. Effect of three level of PS on total wheat grain yield in SC (2012) and FC (2013) periods

Parameter	Treatment (kg ha^{-1})	Year	Mean	SD	n
Total grain yield (kg ha^{-1})	0 K_2SO_4	2012	1777.50	594.99	4
		2013	2297.50	380.28	4
		Total	2037.50	539.40	8
	25 K_2SO_4	2012	2271.25	234.49	4
		2013	2491.93	398.56	4
		Total	2381.59	208.52	8
	35 K_2SO_4	2012	2106.25	655.69	4
		2013	1626.93	467.03	4
		Total	1866.59	585.98	8
	45 K_2SO_4	2012	2147.50	470.97	4
		2013	2361.09	527.82	4
		Total	2254.30	476.96	8
	Total	2012	2075.63	498.54	16
		2013	2194.35	499.92	16
		Total	2134.99	494.80	32

(P = <0.05)

In all treatments, number of spikelet per spike was higher in FC (58, 59, 60 and 58 %) period compared to SC (42, 41, 40 and 42 %). Together, for both FC and SC (n=8) in 25 and 45 kg PS ha^{-1} produced greater number (25.46 and 25.46%) of spikelet per spike than control (24.97%), while 35 kg PS ha^{-1} produced reduced number of spikelet per spike than the control treatment. Collectively, for all treatments (n=16), SC produced less number of spikelet per spike compared to FC (58%). The differences were significant at (P< 0.05).

Thousand grain weight

Effect of different amounts of PS on weight of thousand grains in SC, 2012 and FC, 2013 of wheat *var.Gul 96 was* compared to each other (Table 5). Unlike other variables weight of thousand grains was greater in SC (56, 54 and 53%) for most treatments (control, 25 and 35 kg PS ha^{-1}, compared to FC (44, 46 and 47%), respectively. While, in 45 kg PS ha^{-1} for both SC and FC were similar (50%).

Together in both SC and FC, weight of thousand grains was greater (25.40, 25.16 and 24.98 %) in 25, 35, and 45 kg PS ha^{-1} treatments compared to control (24.52%). Collectively for all treatments (n=16), weight of thousand grains was greater in SC (53%) compared to FC (47%). the difference were significant at ($P< 0.05$).

Total grain yield

Effect of different amounts of PS on wheat yield in SC and FC (wheat *var.Gul 96*) was compared (Table 6). Among all treatments (control, 25, 35 and 45 kg PS ha^{-1}), FC wheat production (56, 52, 56 and 52 %) was greater than that SC (44, 48, 44 and 46.7 %). Together in both FC and SC (n=8), 25 and 45 kg PS ha^{-1}resulted in greater yield (27.89 and 26.40 %), respectively compared to control (23.86%), while 35 kg PS ha^{-1} produced about 2 percent lower (21.86%) yield than control. Collectively (n=16), for all treatments FC wheat total yield (51%) was greater than that SC (49%). The differences were significant at ($P< 0.05$).

DISCUSSION

SC in 2012

Effect of PS on wheat plant biology and total production were inconsistent in SC. Plant height was different from 25 to 26 % among all treatments. Compare to control, only one treatment (25 kg PS ha^{-1}) showed 26 % improvement in plant height. Likewise, spike length was different from 24 to 26% among all treatments, and 45 kg PS ha^{-1} produced longer spikes (26 %) compared to all other treatments. Number of productive tiller per plant was different from 22 to 27 % among treatments. Both 25 and 45 kg PS ha^{-1} treatments had 28 and 27 % improvement on number of productive tillers per plant, respectively. This effect could be as a result of balanced fertilizer application which caused improvement in all plant parts (Jianhua *et al*., 2000). Number of spikelet per spike was varied from 23 to 26% among the treatments; control and 45 kg PS ha^{-1} (26 %) had more spikelets per spike than all other treatments. Weight of thousand seeds was different from 23 to 26% among the treatments. Unlike other parameters both control and 25 kg PS ha^{-1} showed the highest (26%) improvement on weight of thousand grains. Total yield per hectare was varied from 21 to 27 percent. Control had less (21%) and 25 kg PS ha^{-1} showed the highest (27%) yield. Similarly, it was reported that application of 36 kg PS ha^{-1} improved total wheat production and protein contents (Alam *et al*. 2009). Improvement of wheat yield with application of 35 and 45 kg PS ha^{-1} by 25 and 26 % was interesting, and these results suggest that application of PS is obliging for wheat yield enrichment.

FC in 2013

In FC, application of PS had different effects on wheat plant growth and total production. Plant height varied from 24 to 26 % among the treatments. Control had reduced height (24%) compared to 25 and 35 kg PS ha^{-1} (26%) treatments. Likewise, length of spike was different from 24.98 to 25.45 % among the treatments. Control (24.52%) and 45 kg PS ha^{-1} (24.98%) produced shorter and 25 kg PS ha^{-1} produced longer (25.45%) spikes among the treatments.

Number of productive tillers per plant among the treatments varied from 22 to 29 %. Unexpectedly, control produced highest number (29%) of productive tillers per plant. Number of spikelet per spike was different from 25 to 26 % among the treatments, and only 25 kg PS ha^{-1} showed increased (26%) number of spikelet per spike and the rest were identical (25%). Weight of thousand grain weight was different from 23 to 27 % among the treatments. Control treatments had reduced (23%) weight of thousand seeds compared to PS treatments. Total wheat production per hectare varied from 19 to 27 % among the treatments. Both 25 (28%) and 45 kg PS ha^{-1} (27%) showed higher yield compared to 35 kg PS ha^{-1} and control treatments. One of the possible explanations for these variations is expansion of phyto-mass associated to climatic conditions.

Temperature, humidity, day length (photoperiod) have significant influences on phyto-mass accumulation. In our experiment effect of PS was also apparent. Khan found similar results that application of 60 kg PS ha^{-1} not only increased total production about 13 percent, but it had significant impacts on enhancement of phyto-mass, number of spike, length of spike, and total plant height (Khan, *et al*. 2007). Changes in total production of wheat are mostly related to all three essential nutrients (NPK). Availability and balance of these three elements in the soils enable wheat plants to absorb them and raise their grain and total weight of grains. Similar results were reported by Alam, that nutrient balance and application of PS fertilizer increased wheat plant biological mass, grain weight, grain protein content, and total production in Bangladesh (Alam, *et al*. 2009). Another possible explanation for the reduction of some of the parameters is existence of sulfur in PS fertilizer. Increased sulfur concentration in the soil can reduce nutrient balance which may decline wheat plant growth and total production.

Comparison of PS effects between SC and FC

Plant height in both FC and SC was lower in control compared to PS treatments. Total plant height for all treatments was higher in FC compared to SC. Number of cluster bearing stems per plant together for FC and SC was higher in 25, 35 and 45 kg PS ha^{-1} compared to control treatment. This means that all three levels of PS had significant impacts on wheat biology. Likewise, number of spikelet per spike for both FC and SC was less in control compared to 25 kg PS ha^{-1} but was greater than 35 and 45 kg PS ha^{-1} treatments. Similarly, spike length, both, for FC and SC was less in control (24.97%) than 25 and 45 kg PS ha^{-1} (25.26%) and was higher than 35 kg PS ha^{-1} (24.10%) treatment.

This means that PS application had significant effect on wheat yield. Weight of thousand grain weight together for FC and SC was less in control (24.52%) compared to 25, 35 and 45 kg PS ha^{-1} (25.40, 25.16 and 24.98 %, respectively) treatments. This indicates that average amounts of PS improve grain weight, while higher amounts have undesirable effects on grain weight improvement. Likewise, together for FC and SC total wheat production was greater in 25 and 45 kg PS ha^{-1} compared to control, while 35 kg PS ha^{-1} was less than the control. These indicate that first and third doses of PS have positive impact on total yield production, while second dose negatively affect total wheat production.

The results suggest that FC wheat plants had extended time to spread their roots and absorb nutrient from soils. Additionally, FC plants had more time for photosynthesis to enhance their biological growth and grain production. In addition, application of PS improved nutrient balance and increased biological growth and total yield. Similar results were found in an extended research in eight provinces of Afghanistan, where total wheat yield was increased from 3,475 kg ha^{-1} (in control) to 4,435 kg ha^{-1} by application of 120: 120: 120 kg NPK ha^{-1} (Indo-Afghan Annul Report, 1972-1973). Another similar study was conducted in five provinces of the country showed that application of complement fertilizer (150:150 :100 kg K ha^{-1}) increased total wheat yield from 2,692.4 kg to 4,345.5 kg ha^{-1} (Indo-Afghan Annual Report, 1972-1973).

Conclusion

It was concluded that wheat *var. Gul 96*, is a facultative. Effect of PS on wheat plant biological growth and total production in FC and SC were inconsistent. Biological and grain yield in both seasons were increased, which FC PS application showed higher response as compared to SC PS application. The PS positive effects have been observed in both seasons. The optimum doses of PS doses were 25 and 45 kg ha^{-1}. Increased thousand grain weight and high yield resulted by application of 25 and 45 kg PS ha^{-1} in both seasons, while FC wheat response was dominated SC. Thousand grain weight is indicating seeds' vigorousness and rigidity. It has also been observed that average amounts of PS improve grain weight, while higher amounts have undesirable effects on grain weight improvement.

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