CHAPTER 6

PLANT PARAMETERS OF BUCKWHEAT AFFECTED BY THE SOURCES OF NPKS FERTILISERS

6.1 INTRODUCTION

Plants require various major and minor nutrients for their normal growth and development. These nutrients are supplied mainly from the soil and the organic matter. Soils deficient in these nutrients are often supplied with fertilisers, which provide the required amounts of nutrients to the plants. These nutrients are available in different combinations in various commercial fertilisers. Plants vary considerably in their ability to utilise various forms of nutrients in the various fertilisers (Jacobsen *et al.,* 1997).

Dinev and Stancheva (1995) reported that wheat and maize had different responses to N sources. Maize growth in their experiment was maximum with equal combination of NH_4 and NO_3 while NO_3 was more favourable for wheat. Nitrate uptake is favoured at low pH conditions and its absorption can be relatively depressed by NH_4 (Hageman, 1984). Conversely, NH_4 uptake by plant proceeds best at neutral pH value and is depressed by increasing acidity (Guerrero et al., 1981).

Similarly, plant varies in their ability to extract P from fertilisers (Bolland, 1984). Mclean and Logan (1970) reported that 20% acidulated P material was superior to 100% acidulated material in term of yield for six crops grown (including buckwheat) in growth chamber and field. Bjorkman (1998) reported that buckwheat uses mostly insoluble phosphorus source. Very little information is available about K and S nutrition. However, K_2SO_4 is superior as a source of K than KCl but if the cost comparison are made then KCl is much cheaper than K_2SO_4, but the additional disadvantage of KCl is the Cl ion which may be toxic in situation where salinity is a problem or expected to be a problem. Sulfur is a plant nutrient and also a corrective nutrient for soil having higher pH. Many studies have been conducted on the effectiveness of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) sources for various crops and pastures (Robert *et al.,* 1994; Dinev and Stancheva, 1995; Bolland and Bowden, 1984; Boswell, 1987). There are many studies which addresses the P sources for buckwheat but very little is known about N, K, and S nutrient sources. Phosphorus comparison is made for partially acidulated rock phosphate and completely acidulated rock phosphate but few comparison have been made for various soluble and insoluble sources. The present investigation aims to elucidate the influence of different sources of inorganic fertiliser of major nutrients on the yield of buckwheat. This study aimed to investigate the influences of different sources of fertilisers of the major nutrients on the yield of buckwheat.

6.2 MATERIALS AND METHODS

A pot experiment on the response of buckwheat to various sources of N, P, K and S was conducted in the temperate glasshouse at the University of New England, Armidale, and Australia. Two soils i.e. chocolate (Laureldale) and grey brown podsolic (Kirby-17) were tested in this experiment. These soils were collected and prepared according to the procedure explained in Chapter 4. The detail of the soil analysis is given in Table 6.1. Plastic pots with 283.38 cm^2 surface area were filled with these soils. Basal rates of 50, 40, 50, 60, 20 and 20 kg/ha as N, P, K, S, Ca, and Mg, respectively, were applied. Nitrogen was not applied as a basal dressing when N sources were tested. Similarly, P, K, and S were also not added as basal doses when their sources were tested. Micronutrients (zinc, copper, molybdenum and boron) were applied at the rate of 5 kg/ha each as basal rates in each treatment of fertiliser sources. All the basal fertilisers were mixed thoroughly with the soil in each pot before sowing while the fertiliser sources as a treatment were applied after germination and thinning. The description of all the treatments and the fertiliser calculations for each treatment are summarised in the following sections.

6.2.1. Description of Treatments

T1 = Urea $\{CO(NH_2)_2\}$, **T2** = Nitram (NH_4NO_3), **T3** = Ammonium Sulphate [$(NH_4)_2SO_4$], **T4** = Partially Acidulated Rock Phosphate (PARP), **T5** = Rock Phosphate ("RP" from North Carolina, USA), **T6** = Single Super Phosphate (SSP), **T7** = Triple-super Phosphate (TSP), **T8** = Potassium Sulphate (K_2SO_4), **T9** = Potassium Chloride (KCl), **T10** = Potassium Sulphate (K_2SO_4 as S source), **T11** = Elemental Sulfur (ES), **T12** = Calcium Sulphate ($CaSO_4$), **T13** = Control (no nutrients applied).

6.2.2. Fertiliser Calculations

Fertilisers and analytical grade chemicals were weighed separately for each of the above treatments as follows.

T1 Fertilisers/chemicals weighed were 0.31 g of urea $\{CO(NH_2)_2\}$ (50 kg/ha N) as a major treatment of nitrogen sources, 0.492 g of KH_2PO_4 as 40 kg P/ha; this also supplied 50.36 kg/ha of K. Ca was applied @ 20 kg/ha as

$CaSO_4$ (0.246 g/pot); this also added 16 kg S/ha. Magnesium @ 20 kg/ha as $MgSO_4$. $7H_2O$ (0.584 g/pot) which also supplemented 27 kg/ha S. Copper was applied @ 5 kg/ha as $CuSO_4.5H_2O$ (0.055 g/pot) which provided 2.5 kg/ha S as well. The amount of sulfur supplemented by any fertiliser was calculated and subtracted from the actual rate of 60 kg/ha S and the rest was added through Na_2SO_4. Molybdenum was applied @ 5 kg/ha as $Na_2MoO_4.2H_2O$ (0.036 g/pot) while boron was added @ 5 kg/ha as H_3BO_3 (0.08 g/pot).

T2 Nitram (NH_4NO_3) @ 50 kg/ha (0.42 g/pot) was used as the nitrogen source and the rest of the nutrients were mixed in the same manner as indicated in **T1**.

T3 Ammonium sulphate $(NH_4)_2$ SO_4 @ 50 kg/ha N (0.674 g/pot) as a major treatment of N source was applied. K was supplemented with KH_2PO_4 as the P source and S with $(NH_4)_2 SO_4$ as the N source. Calcium was added as $Ca(CH_3COO)_2H_2O$ (0.223g); Magnesium was added as $MgCl_2.6H_2O$ (0.479g). Zinc was applied as $ZnCl_2$ (0.029g). Copper, molybdenum and boron were applied as indicated in **T1**.

T4 Rock phosphate was used as a P source @ 40 kg/ha (0.891 g/pot) as a major treatment of P; urea as the N source @ 50 kg/ha (0.31g); K as KCH_3COO (0.354g); Sulfur as Na_2SO_4 (0.334g). The rest of nutrients were applied in the same way as described in **T1**.

T5 The same nutrients with the same weight were applied as mentioned in **T4** except PARP was applied as a P source (0.891g) @ 40 kg P/ha.

T6 Single super phosphate (SSP) was applied as a P source @ 40 kg/ha (1.29 g/pot) as major treatment of P; Urea as the N source (0.31g). K as KCH_3COO (0.354g). Sulfur as Na_2SO_4 (0.06g); Calcium as $Ca(CH_3COO)_2$ .H_2O (0.223 g); Magnesium as $MgCl_2.6H_2O$ (0.479g). A similar amount and form of zinc, copper, molybdenum and boron was applied as described in **T1**.

T7 All the nutrients and their amounts were the same as described in **T6**, except triple-super phosphate was applied as the P source.

T8 KCl was applied as the major K source @ 50 kg/ha (0.27g). Urea as the N source @ 50 kg/ha (0.31g). TSP was applied as the P source

(0.647g). Sulfur, calcium, magnesium, zinc, copper, molybdenum and boron were applied as described in **T1**.

T9 K_2SO_4 was applied as the major of K source, while urea was used for N, triple super phosphate for P, $Ca(CH_3COO)_2H_2O$ for calcium, $MgSO_4.7H_2O$ for magnesium, $ZnCl_2$ for zinc, $CuSO_4.5H_2O$ for copper, $Na_2MoO_4.2H_2O$ for molybdenum and H_3BO_3 for boron as basal nutrients.

T10 Elemental sulfur was applied as the sulfur source (0.164 g/pot); N as urea, P as KH_2PO_4, magnesium as $MgCl_2.6H_2O$, calcium as $Ca(CH_3COO)_2H_2O$, and zinc as $ZnCl_2$, while copper, molybdenum and boron were applied as basal nutrients as in **T1**.

T11 $CaSO_4$ was used as the treatment source of sulfur. All other nutrient sources were the same as used in **T10**, except for $CuCl_2.2H_2O$ as the copper source.

T12 Ammonium sulphate $(NH_4)_2SO_4$ was applied as a major treatment of sulfur source. P was applied as KH_2PO_4, calcium as $Ca(CH_3COO)$, magnesium as $MgCl_2.6H_2O$, zinc as $ZnCl_2$, copper as $CuCl_2.2H_2O$, $Na_2MoO_4.2H_2O$ for molybdenum and boron as H_3BO_3 were applied as basal nutrients.

T13 Control, replicated 3 times but no nutrients applied.

6.2.3. Experimental Design and data recording

The experiment was set up in a randomised complete design with three replications for each treatment. Pots were shuffled in the glasshouse on weekly basis to reduce the variability of temperature variations prevailing in the glasshouse. Eight seeds of Mancan variety were sown in each pot. All the pots were thinned to four plants in each pot. The pots were kept at field capacity throughout the growing period. Data on plant height were recorded during the growth period 35 days after sowing. Plants were harvested at maturity, dried in the oven at a temperature of 80°C for 48 hours. Data on the straw and grain yield were recorded after drying of the plants.

6.2.4. Soil analysis

The soil analysis for the chocolate and grey brown podsolic soils were carried out at the Incitec analytical laboratories, Port Kembla, NSW. The detail of the methods used for these analyses is described in Chapter 5, Section 5.2.2.

6.2.5. Data presentation and statistical analysis

Data for the different plant parameters as plant height, straw yield and grain yield on the chocolate and grey brown podsolic soils are presented separately. Data were analysed separately for the sources of each nutrient using the NEVA (Version 3.3) analysis of variance computer program (Burr, 1980). Mean separations was determined using the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$.

Table 6.1. Soil analysis of the chocolate and grey brown podsolic soils.

Properties	Chocolate	Grey Brown Podsolic
Colour (Munsell)	Very Dark Greyish Brown	Greyish Brown
Texture	Light Clay	Sandy Loam
pH (1:5 water)	5.4	5.8
pH (1:5 $CaCl_2$)	4.8	4.9
Organic Carbon %C	2.9	1.2
Nitrate Nitrogen mg/kg	65	11
Sulfate Sulfur (MCP) mg/kg	15	3
Sulfate Sulfur (KCl-40) mg/kg	7	3
Phosphorus (Colwell) mg/kg	61	9
Potassium meq/100g	0.4	0.2
Calcium meq/100g	18.5	2.1
Magnesium meq/100g	13.3	1.1
Aluminium (KCl) meq/100g	0.14	0.11
Sodium meq/100g	0.27	0.07
Chloride mg/kg	11	6
Electrical Conductivity dS/m	0.27	0.04
Copper mg/kg	3.2	<0.5
Zinc mg/kg	1.7	7.5
Manganese mg/kg	91	8
Iron mg/kg	96	41
Boron mg/kg	0.5	0.2

6.3. RESULTS

6.3.1. Chocolate soil

i) Plant height

There was no significant difference in the plant height produced with various sources of N, P, K, and S, even over control. Non of the sources was significantly different from the control (Table 6.2).

Table 6.2. Plant height, straw and grain yields of buckwheat affected by sources of N, P, K, & S in chocolate soil.

Nutrient	Sources	Plant height (cm)	Straw yield (g/pot)	Grain yield (g/pot)
Nitrogen	Control	39.34	13.91	9.80
	Urea	37.17	20.07	10.51
	$(NH_4)_2SO_4$	40.95	19.29	12.66
	NH_4NO_3	35.06 NS[a]	22.89 NS	13.67 NS
Phosphorus	Control	39.34	13.91 B	9.80 C
	PARP	40.67	21.00a A	12.57ab AB
	RP	37.89	19.48a A	11.87ab B
	SSP	43.39	22.26a A	11.51b B
	TSP	39.11 NS	20.88a A	13.36a A
Potassium	Control	39.34	13.91 B	9.80
	K_2SO_4	43.17	22.67a A	11.51
	KCl	44.05 NS	21.48a A	12.47 NS
Sulfur	Control	39.34	13.91	9.80 C
	K_2SO_4	43.17	22.67	11.51b BC
	ES	42.05	23.87	14.16a A
	$CaSO_4$	39.17	19.04	11.58b BC
	$(NH_4)_2SO_4$	39.55 NS	15.24 NS	13.61ab AB

Numbers followed by the same letter (lower cases) within a column for a nutrient sources are not significantly different according to DMRT $P \leq 0.05$.

Numbers followed by the upper cases within a column for each nutrient represent the comparison of control with nutrient sources.

NS[a]= Non-significant

ii) Straw yield

There was no significant difference in the straw yield with various sources of N, P, K, and S. However, the sources of P and K produced significant increases over control while sources of N and S caused no significant increase in straw over control (Table 6.2).

iii) Grain yield

No significant difference in the grain yield was observed among the sources of each of N, and K. All the sources produced statistically similar grain yield to control (Table 6.2).

There were significant differences in the grain yields due to sources of P. The highest grain yield was obtained with triple-super phosphate (TSP) which was statistically similar to PARP and RP but significantly higher than SSP, which in turn was statistically similar to PARP and RP but significantly lower than TSP. All the P sources produced significantly higher (average 21%) yields over the control.

There was significant difference in the grain yield due to sources of S. Elemental sulfur (ES) produced the highest grain yield, which was statistically similar to the yield obtained with ammonium sulphate [$(NH_4)_2SO_4$]. The application of potassium sulphate (K_2SO_4), calcium sulphate ($CaSO_4$) and $(NH_4)_2SO_4$ produced statistically similar yields. The sources were ranked numerically as ES > $(NH4)_2SO_4$ > gypsum > K_2SO_4 (Table 6.2). There were significant increases in grain over the control due to ES and $(NH4)_2SO_4$, however, K_2SO_4 and $CaSO_4$ were statistically similar to control.

6.3.2. Grey brown podsolic soil

i) Plant height

There were no significant differences in plant height among the sources of each of N, K, and S, however, the sources of P resulted in significant differences in height. PARP produced the highest plant height but was statistically similar to SSP and TSP. The lowest height was recorded where rock phosphate (RP) was applied, which was significantly lower than the PARP but statistically similar to other sources of P (Table 6.3).

When the sources of N, P, K, and S were compared to control, all produced significantly higher heights with the exception of RP, which produced similar height to the control. Average increases in plant heights compared to the control due to sources of N, P, K, and S were recorded as 56%, 36%, 62%, and 56%, respectively (using data in Table 6.3).

ii) Straw yield

Straw yield was significantly affected by the sources of N. Urea among other sources of N produced the highest straw yield, which was significantly different from the yield obtained with ammonium sulphate and ammonium nitrate. However, the application of ammonium sulphate and ammonium nitrate produced statistically similar straw yields (Table 6.3).

There was also significant effect on the straw yield due to the application of sources of P. Triple-super phosphate produced the highest straw yield amongst the sources of P, but it was statistically similar to SSP and PARP. The lowest straw yield was obtained with the application of RP, which was statistically similar to PARP (Table 6.3).

There was no significant effect on the straw yield due to the sources of K and S. However, all the sources of N, P, K, and S produced significantly higher yields over control (Table 6.3). The average increases in straw yield over control due to sources of N, P, K, and S were 73%, 69%, 72%, and 73%, respectively.

iii) Grain yield

There was significant effect on the grain yield due to the application of various sources of P. The SSP source of P produced the maximum grain yield which was statistically similar to the yield obtained with TSP, and PARP. The lowest grain yield was obtained with the application of RP, which was statistically similar to the yield in PARP and TSP but significantly lower than SSP (Table 6.3). All the sources produced significantly higher grain yields over the control.

Among the sources of S, gypsum produced the top grain yield, which was statistically similar to the yield in K_2SO_4. There was no statistical difference in the yield produced with the application of K_2SO_4, ES, and $(NH_4)_2SO_4$ (Table 6.3). All the sources of S produced significantly higher yields over control.

There was no significant difference in the grain yields among the sources of each of N and K, however, all the sources of these elements significantly increased the yield over control with the exception of urea which produced a similar yield to the control (Table 6.3).

Table 6.3. Plant height, straw and grain yield as affected by the sources of N, P, K, and S on the grey brown podsolic soil.

Nutrient	Sources	Plant height (cm)		Straw yield (g/pot)		Grain yield (g/pot)	
Nitrogen	Control	13.28	B	4.88	C	1.93	B
	Urea	31.08a	A	20.13a	A	4.56a	AB
	$(NH_4)_2SO_4$	27.43a	A	17.23b	B	5.52a	A
	NH_4NO_3	32.39a	A	16.97b	B	6.76a	A
Phosphorus	Control	13.28	C	4.88	C	1.93	C
	PARP	24.08a	A	15.97ab	AB	4.70ab	AB
	RP	17.65b	BC	13.33b	B	3.78b	B
	SSP	21.16ab	AB	16.20a	A	5.82a	A
	TSP	19.56ab	AB	16.65a	A	4.93ab	AB
Potassium	Control	13.28	C	4.88	B	1.93	B
	K_2SO_4	31.61a	B	17.95a	A	5.90a	A
	KCl	38.73a	A	17.41a	A	6.35a	A
Sulfur	Control	13.28	B	4.88	B	1.93	C
	K_2SO_4	31.61a	A	17.95a	A	5.90ab	AB
	ES	32.63a	A	19.73a	A	4.75b	B
	$CaSO_4$	29.17a	A	15.57a	A	7.28a	A
	$(NH_4)_2SO_4$	26.93a	A	19.23a	A	4.86b	B

Numbers followed by the same letter (lower cases) within a column for a nutrient sources are not significantly different according to DMRT $P \leq 0.05$.

Numbers followed by the upper cases within a column for each nutrient represent the comparison of control with nutrient sources.

6.4. DISCUSSION

As mentioned earlier, chocolate soil was sufficient in the native N (65 mg/kg NO_3-N). Due to lack of knowledge on the required levels of nutrients in the soil for buckwheat, the current results are compared to wheat, oat, and barley. Based on the N requirements of these crops, no N application was required on this soil (Soil Interpretation Mannual, 1990). The non-significant increase in yield over control due to application of N confirms that N was sufficient for buckwheat and further addition may not be beneficial. However, the response of chocolate soil in the nutrient soil (Chapter-5) could be associated with limited amount of soil (0.5 kg/pot) which hardly supplied 32.5 mg NO_3-N to yield dry matter of 20.5 g, resulting in possible tissue level of 0.16%.

So, the response to N was mainly because of the inadequate total NO_3-N available for the plant and not due to lower NO_3-N concentration per se.

There was a significant increase in the yield when nitrogen was added to the grey brown podsolic soil. The yield response to N could be the initially low level of N based on the Soil Interpretation Mannual (1990). However, the sources did not show any difference in plant measurement except straw yield where urea was superior. Once again by comparing the two soils, chocolate soil outyielded grey brown podsolic soil at each treatment. This confirms the superiority of chocolate soil over other soil types and the reason may be its high fertility.

The addition of P increased straw and grain yield significantly over control in chocolate and grey brown podsolic soils (Table 6.2 and 6.3). The highest grain yield was obtained with the application of TSP in chocolate soil and with SSP in Grey brown podsolic soil which are water-soluble sources of P. There were no significant variations among values of straw yield produced by SSP, PARP, and RP treatments in the chocolate soil, but RP produced significantly lower straw yield than other sources of P in the grey brown podsolic soil. The grain yield obtained with TSP was significantly greater than the SSP but similar to PARP and RP in chocolate soil but in case of grey brown podsolic soil, only RP produced significantly lower grain yield than SSP.

Many studies have shown that PARP is as effective as super phosphate (McLean and Wheeler, 1964; McLean *et al.*, 1965; McLean and Balam, 1967; Hammond *et al.*, 1986; Chien and Hammond, 1989). Myers and Meinke (1994) have quoted that buckwheat is effective in capturing soil P, or P from rock phosphate fertilisers. Bjorkman (1999) reported that buckwheat is the most effective user of rock phosphate and can effectively utilise the most insoluble source of P.

Given the low pH of chocolate and grey brown podsolic soils (4.8 and 4.9, respectively) and the ability of buckwheat to further acidify the soil (Van Ray and van Diest, 1979), the expected differences in the yield of buckwheat due to P sources have been marginalized. Similarly, the comparable yield obtained with PARP and TSP (Table 6.2 and 6.3) is probably associated with the ability of buckwheat to utilise the insoluble P sources efficiently in the acidified soil buckwheat system.

These results suggest that in low pH ($\leq$5.0) soils, the P sources are equally effective in buckwheat production irrespective of their degree of solubility.

Irrespective of the sources, K application at the rate of 50 kg/ha to chocolate soil increased straw yield significantly over control with no effect on the grain yield (Table 6.2). This soil contained 0.4 meq/100g, which is considered optimum for the production of grain sorghum, wheat, and oats and as such no application of K was required on this soil for increasing buckwheat yield. This observation is supported by the findings of Murayama *et al.*, (1998) who reported that the application of K had little influence on the grain yield of buckwheat when compared to control. Current findings indicate that the non-significant increase in grain yield may be due to its initially high level, however, there are findings that indicate the beneficial effect of K when applied in combination with other nutrients under various soil and climatic conditions (Anokhin and Martynenko, 1976; Kolosova, 1977; Szklarz and Olender, 1986; Glazova, 1998).

In case of grey brown podsolic soil, both the K sources caused a significant increase in the straw and grain yield of buckwheat (Table 6.3). This soil contains 0.2 meq/100g soil, which is lower by a factor of 2 than the level of K in the chocolate soil. Potassium application to this soil was reportedly beneficial to wheat, oats and barley (Soil Interpretation Manual, 1990). Similar to chocolate soil, sources of K did not show any significant difference in their effect on the plant yields suggesting that the K sources used in this study were equally effective for the yield of buckwheat.

The addition of S significantly increased the yield over control in both chocolate and grey brown podsolic soils. This may be due to the low level of native S concentration of 7 and 3 mg/kg in chocolate and grey brown podsolic soil, respectively. The addition of various sources of S increased the grain yield over control from 17.3 - 44.5% in chocolate soil and from 146 - 277% in the grey brown podsolic soil. The higher magnitude of increase in the grey brown podsolic soil is associated with its lower level of initial S (3 mg/kg) and with lower level of yield produced by control (Table 6.2 and 6.3).

By comparing the various sources of S fertilisers, elemental sulfur (ES) was more beneficial in terms of yield increase over control (44.5%) followed by $(NH_4)_2SO_4$ (39%), while K_2SO_4 and $CaSO_4$ performed identical (17.3%) in the chocolate soil. The maximum increase in yield due to ES may be associated with the slow release of S and its sustained availability to plants throughout the growing period from the ES. The poor performance by K_2SO_4 may be because of its higher solubility which let to substantial amount of leaching of sulfate-S from root zone, while that of $CaSO_4$ could be related to its restricted release of S due to low solubility or it may also be associated with the leaching of sulfate. These results are in conformity with the findings of several researchers who conducted experiments on the effect of various sources of S. Shedley

(1982), Bowdler and Pigott (1990) have reported that sulfate-containing products, such as gypsum and K_2SO_4 generally contribute sulfate to growing crops more quickly than the elemental S. However, the leaching losses of S from these sources are higher (Morris 1987). The beneficial effect of $(NH_4)_2SO_4$ was statistically similar to ES which could be associated with the preferential uptake of NH_4 ions by the buckwheat plants from the soil thereby acidifying the root zone which promotes the dissolution of P and other nutrients and eventually increase the yield of crop (Van Ray and van Diest, 1979).

In case of grey brown podsolic soil, ES and $(NH_4)_2SO_4$ caused a net increase of 146 and 152% over control while K_2SO_4 and gypsum increased the grain yield by 206 and 277%, respectively, suggesting that gypsum and K_2SO_4 were more effective than ES and $(NH_4)_2SO_4$. The better response of the grey brown podsolic soil to addition of S source of K_2SO_4 and gypsum could be associated with the effect of K and Ca as this soil contains about 0.2 and 2.1 mg/100g K and Ca, respectively. So the addition of these two sources provided the required amount of K and Ca which promoted the yield of buckwheat and this observation is corroborated by the response of this soil to the application of K (Table 6.3) while in case of chocolate soil the effect of K and Ca was less pronounced as this soil has adequate in both the nutrients.

On the basis of these findings it is suggested that the effect of associated cation and the initial level of the various nutrients of the soil should be taken into account while interpreting the effect of S sources on buckwheat.

CHAPTER 7

EFFECTS OF NITROGEN, PHOSPHORUS, POTASSIUM AND SULFUR ON THE YIELD OF BUCKWHEAT ON DIFFERENT SOILS OF NEW ENGLAND TABLELANDS

7.1. INTRODUCTION

Fertile soils are one of the most important resources on the earth. Such resources should be used in a way that the present and future human needs for food or other agricultural goods are guaranteed from sustainable agriculture. At the same time the quality of the environment and the natural resources are preserved. Among others, the use of nutrients in agriculture causes environmental problems which need to be solved whilst still maintaining profitable agriculture. One major problem is that the variability of soil fertility features together with the uniform fertiliser to fields causes inefficient utilisation and unnecessary environmental burdens as there could be both under and over application of fertiliser.

The nutritional requirements of buckwheat as related to soil types, are not yet described. These are the focus of the current study. The field experiments described in this Chapter were initiated to investigate if buckwheat responds to the nutrients on the agriculturally important soils of the New England Tablelands.

7.2. MATERIALS AND METHODS

Field trials were conducted at various locations on the farmer fields around Armidale in the New England Tablelands. The first field experiment was attempted on a local farm on Guyra road, Armidale, during 1995-96. Two field trials were attempted at two other farmer's fields during 1996-97. The data of these trials could not be collected due to the unusual heavy rains and damage by the weeds. In 1997-98, three field trials were conducted at the properties Coventry, Laureldale and McClenaghan. The data from one field trial (McClenagan) was not worthy of presentation due large variations in the treatments caused by birds and kangaroo damage to the crop. The soil types were yellow podsolic at Coventry, on the Grafton road and a chocolate at Laureldale, research farm of the University of New England, Armidale, where the trials were successfully conducted.

A 2^4 factorial design with the factors nitrogen (N), potassium (K), sulfur (S) and phosphorus (P) was established. The treatments NKS were applied at rates of 0 and 50 kg/ha and P at 0 and 40 kg /ha. The random allocation of these treatments to each replication (block) and the layout of the experiment are presented in Table 7.1. A composite soil sample from 20-25 cores was collected from the experimental area of each site for soil analysis. The results of the soil analyses are presented in Table 7.2. The plot size for each treatment was 4 x 2 m with a 25 cm row spacing. Mancan variety was sown at the rate of 50 kg/ha. The sowings were done on 19th and 23rd of December at Coventry and Laureldale, respectively during 1997.

The trials were monitored by frequent visits to each site to observe any visual disorders on the crop during the growth period. Weeding and thinning were done manually where needed. The crop was harvested at maturity on 5th and 12th of March 1998 at Coventry and Laureldale, respectively. Sample area of 1x0.5 m^2 was harvested from the centre of each plot. Plant tops were dried in a forced drought oven at 80°C. Grain yield of each plot was recorded after thrashing.

Table 7.1. Experimental Layout for the field trials.

R_1	N	SP	K	SKP	SN	NIL	SK	KN	P	SKN	KNP	SKNP	NP	SNP	S	KP
R_2	KN	SK	P	SKNP	KP	SKN	SN	K	S	N	NIL	SP	NP	SKP	SNP	KNP
R_3	S	SKNP	SP	SNP	SKP	N	KP	NP	SK	KNP	P	KN	K	SN	NIL	SKN
R_4	NIL	SN	K	SKP	KNP	P	S	SP	N	SNP	KP	NP	SKN	KN	SKNP	SK

7.2.1. Data analysis

The straw and grain yield data for each site were analysed as a 2^4x4 replicate factorial using the NEVA (Version 3.3) analysis of variance computer program (Burr, 1980). Mean separation was determined using the Duncan's Multiple Range Test (DMRT) ($P \leq 0.05$ probability).

7.2.2. Soil analysis

All the soil chemical analysis (Table 7.2) were carried out at the Incitec analytical laboratories, Port Kembla, NSW. The detail of the methods used for these analysis are described in Chapter 4, Section 4.2.2.

Table 7.2. Soil analysis of Laureldale and Coventry sites.

Properties	Laureldale	Coventry
Soil Type	Chocolate	Yellow Podzolic
Colour (Munsell)	Very Dark Greyish Brown	Pale brown
Texture	Light Clay	Coarse Sandy Clay Loam
PH (1:5 water)	5.4	5.5
PH (1:5 $CaCl_2$)	4.8	4.5
Organic Carbon %C	2.9	1.1
Nitrate Nitrogen mg/kg	65	<2
Sulfate Sulfur (MCP) mg/kg	15	Not determined
Sulfate Sulfur (KCl-40) mg/kg	7	4
Phosphorus (Colwell) mg/kg	61	6
Potassium meq/100g	0.4	0.16
Calcium meq/100g	18.5	1.2
Magnesium meq/100g	13.3	0.5
Aluminium (KCl) meq/100g	0.14	0.33
Sodium meq/100g	0.27	<0.05
Chloride mg/kg	11	<5
Electrical Conductivity dS/m	0.27	0.02
Copper mg/kg	3.2	0.20
Zinc mg/kg	1.7	0.10
Manganese mg/kg	91	9.0
Iron mg/kg	96	74.0
Boron mg/kg	0.5	0.30

7.3. RESULTS

7.3.1. Coventry site

i) Straw yield

The treatments of N_{50}, P_{40}, K_{50}, and S_{50} were initially compared to the straw yield obtained with Nil and statistically analysed separately to see the effects of each nutrient alone on the yield (Figure 7.1). It was recorded that the application of N alone significantly increased the straw yield by more than 120% over Nil. The application of each of P, K and S alone failed to increase the straw yield and produced statistically similar yield to Nil. The application of P alone produced significantly lower yields over Nil.

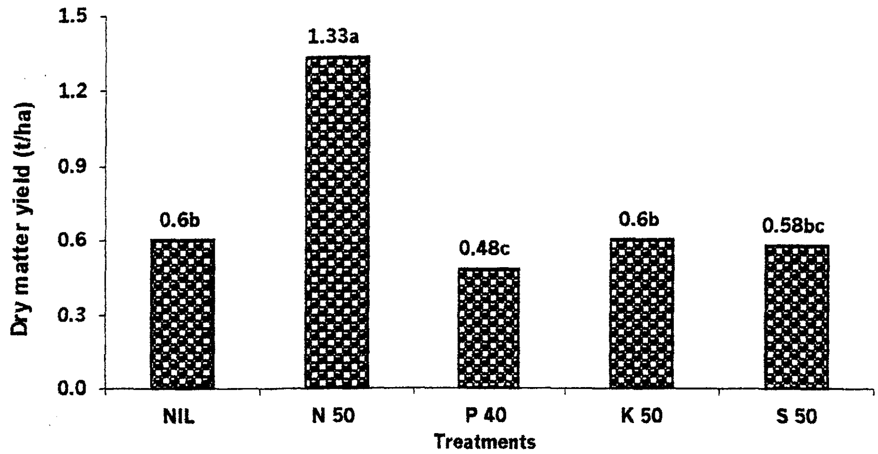

Figure 7.1. Effects of N, P, K, and S on the straw yield in comparison with NIL at Coventry.

Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$

The data in Table 7.3 represent the straw yield as affected by the main effects of N, P, K, and S at Coventry site (yellow podsolic soil). The mean values (n=32) were averaged for the two levels of the respective nutrients. It was observed that the presence of each of N, P, and S increased the straw yield by 156%, 12%, and 13%, respectively compared to their respective yields where these nutrients were absent.

Table 7.3. Average (n=32) straw yield (t/ha) as affected by the application of N, P, K, and S at Coventry.

Rate	0 kg/ha	50 kg/ha
Nutrients		
Nitrogen	0.60b	1.54a
Phosphorus*	1.01b	1.13a
Potassium	1.08a	1.05a
Sulfur	1.00b	1.13a

Numbers followed by the same letters within a row are not significantly different according to DMRT $P \leq 0.05$.

*Phosphorus (40 kg/ha)

The overall effects of N, P, K, and S and their interactions on the straw yield are reported in Table 7.4. The data represent the means of 4 replications for the respective treatments. It is obvious from the data that application of 50 kg N/ha caused significant increase in the straw yield over those treatments that did not received N (Table 7.4). With the exception of N+K treatment which showed non-significant difference in yield as compared to N alone. All the other treatments where N, P, K, and S were applied in the given combinations produced significantly higher yields suggesting that P and S showed synergistic effect on the yield when applied with N (Table 7.4).

The effects of each significant treatment are discussed separately in the following sections.

Table 7.4. Straw yield (t/ha) affected by N, P, K, and S and their interactions at Coventry.

Treatment	Straw yield (t/ha)	Treatment	Straw yield (t/ha)
NIL	0.60	N	1.33
K	0.60	KN	1.25
S	0.58	SN	1.68
SK	0.50	SKN	1.53
P	0.48	NP	1.53
KP	0.48	KNP	1.78
SP	0.80	SNP	1.70
SKP	0.78	SKNP	1.53

LSD (0.05) = 0.19 t/ha

S x K interaction

Figure 7.2 represents means of 8 treatments averaged across K_0 and K_{50} for the S x K interaction. The application of 50 kg S/ha produced significantly higher straw yield compared to zero S or K alone. Application of 50 kg/ha of K showed no significant effect on the straw yield at 0 level of S but rather depressed the yield significantly when applied with 50 kg/ha of K (Figure 7.2). This depression was statistically significant.

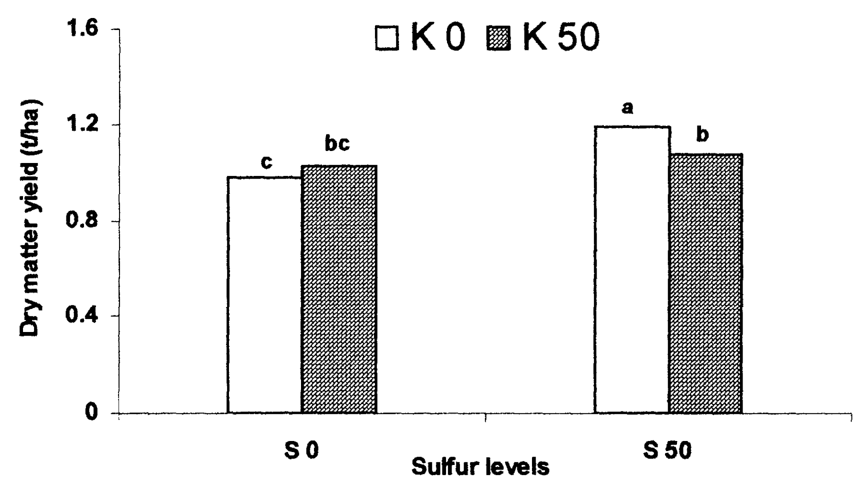

Figure 7.2. Straw yield as affected by the interactions of S x K at Coventry.

Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$

S x P x N interaction

Application of N_{50}, P_{40} and S_{50} resulted in a significant interaction of the straw yield (Figure 7.3). The application of S with N, or P with N, or P and S both with N produced statistically similar straw yields but significantly higher than N alone. The highest increase (28%) over N alone was observed due to combination of N and P. On the other hand, the combined application of P and S in the absence of N produced significantly higher yield over all other treatments where N was a limiting factor. However, all the straw yields produced in the absence of N were significantly lower than the straw yields where N was applied.

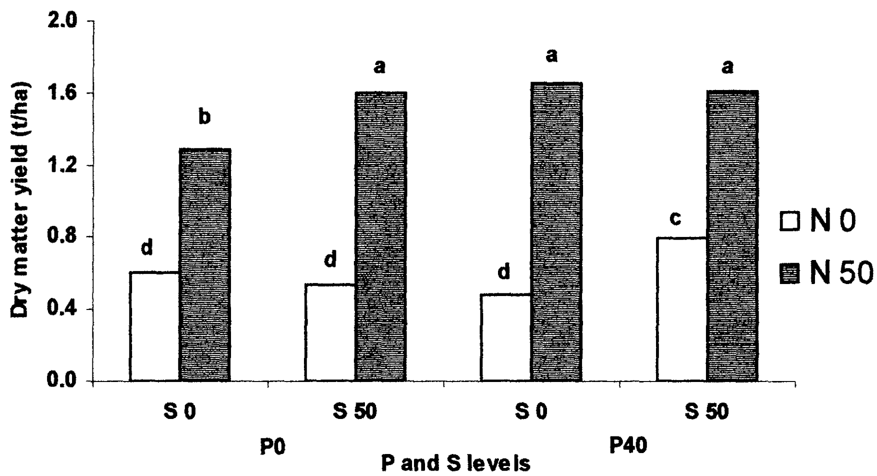

Figure 7.3. Straw yield as affected by the interaction of S x P x N at Coventry.

Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

ii) Grain yield

The treatments of N_{50}, P_{40}, K_{50}, and S_{50} were initially compared to the grain yield obtained with Nil and statistically analysed separately to see the effects of each nutrient alone on the yield (Figure 7.4). This was done to simulate a farmer applying an individual fertiliser such as urea, elemental sulfur, potassium chloride or triple-super phosphate. There was a significant increase in the grain yield (136%) with the application of N over Nil (Figure 7.4). The grain yields produced with the application of each of P, K, and S were statistically similar to Nil.

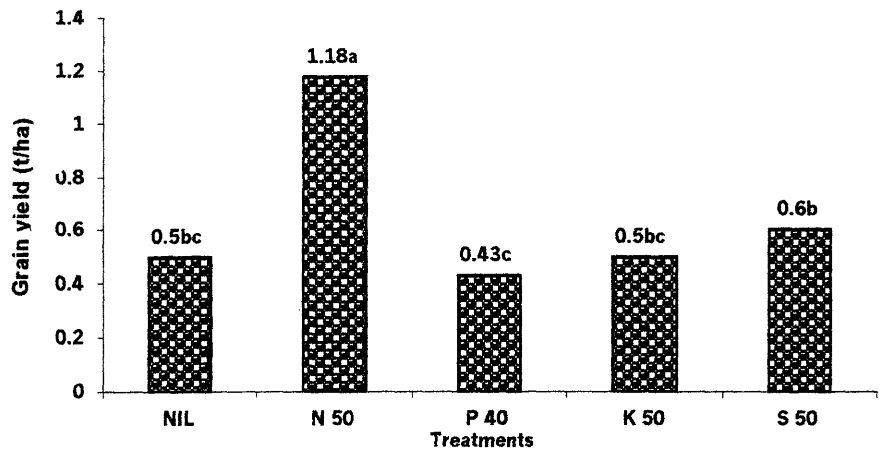

Figure 7.4. Grain yield as affected by the application of N, P, K, and S in comparison with NIL at Coventry.

Numbers followed by the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

The data in Table 7.5 represent the grain yield as affected by the main effects of N, P, K, and S at Coventry site (yellow podsolic soil). The mean values (n=32) were averaged for the two levels of the respective nutrients. It was observed that the presence of N significantly increased (151%) the average grain yield over the yield where N was a limiting factor. Similarly, the application of P and S each also significantly increased the average grain yield by 12% and 10%, respectively over the grain yields where these nutrients were absent. However, the application of K depressed the average grain yield significantly by 7% compared to the yields where K was absent.

Table 7.5. Average (n=32) grain yield (t/ha) as affected by the application of N, P, K, and S at Coventry.

Rate	0 kg/ha	50 kg/ha
Nutrients		
Nitrogen	0.49b	1.23a
Phosphorus*	0.81b	0.91a
Potassium	0.89a	0.83b
Sulfur	0.82b	0.90a

Numbers followed by the same letters within a row are not significantly different according to DMRT $P \leq 0.05$.

*Phosphorus (40 kg/ha)

The overall effects on the grain yield due to the application of N, P, K, and S nutrients and all their interactions are presented in Table 7.6. Similar to the straw yield, the grain yield increased significantly in the treatments where N was applied alone or in combinations with P, K, and S as compared to the treatments where N was absent. The magnitude of increase was almost the same as was observed in straw yield. The effects of all significant treatments are discussed separately in the following sections.

Table 7.6. Grain yield (t/ha) affected by N, P, K, S, and their interactions at Coventry.

Treatment	Grain yield (t/ha)	Treatment	Grain yield (t/ha)
NIL	0.50	N	1.18
K	0.50	KN	1.0
S	0.60	SN	1.10
SK	0.38	SKN	1.23
P	0.43	NP	1.38
KP	0.35	KNP	1.23
SP	0.65	SNP	1.30
SKP	0.55	SKNP	1.43

LSD (0.05) = 0.15

N x P interaction

There was a significant effect on the grain yield due to the interaction of N_{50} x P_{40} (Figure 7.5). The grain yield was significantly increased (17%) when P was applied in combination with N over N alone. However, the application of P alone without N did not show any increase over no P application.

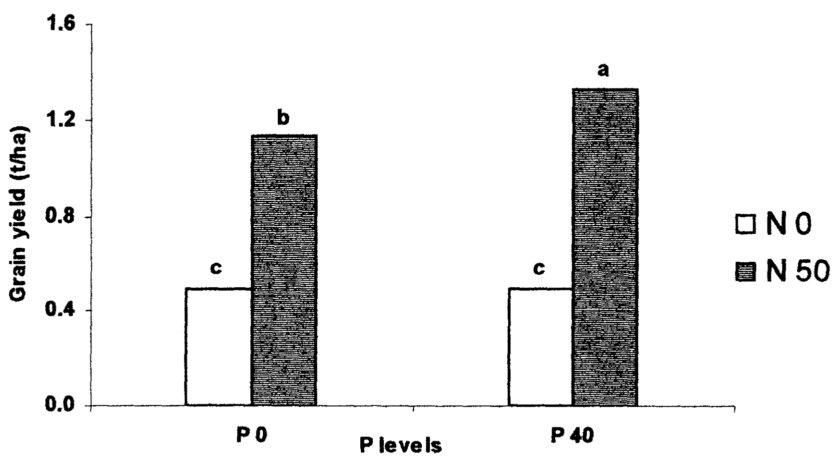

Figure 7.5. Grain yield as affected by the interaction of N x P at Coventry.

Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

S x K x N interaction

The grain yield obtained with the application of N_{50} alone was statistically similar to the highest grain yield obtained with the combination of N_{50}+K_{50}+S_{50} (Figure 7.6). The separate application of K and S each in combination with N produced statistically similar grain yields but significantly lower than the highest yield. The application of S alone produced significantly higher grain yield than zero S but significantly depressed the yield when applied in the presence of K. All the yields produced in the absence of N were significantly lower than those where N was applied.

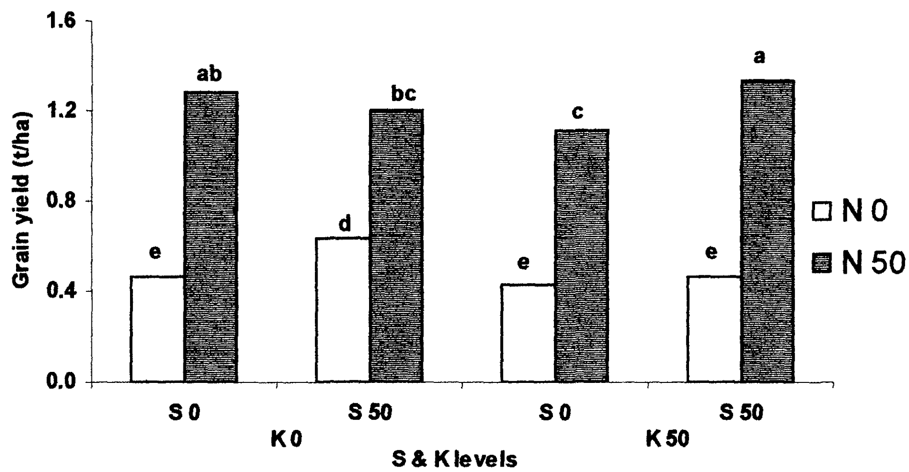

Figure 7.6. Grain yield as affected by the interaction of S x K x N at Coventry.
Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

S x P x N interaction

The interaction of S_{50} x P_{40} x N_{50} significantly affected the grain yield. The highest grain yield was obtained with the combination of S+P+N, which was statistically similar to P+N and both of these yields were significantly higher than all other yields in this interaction (Figure 7.7). Similarly, there was no significant difference in the grain yields between N alone and N+S. On the other hand, the application of S resulted in no significant increase over zero S, P alone or P+S; however, the yield produced with P+S was significantly higher than the P alone. All the grain yields produced in the absence of N were significantly lower than those grain yields where N was applied.

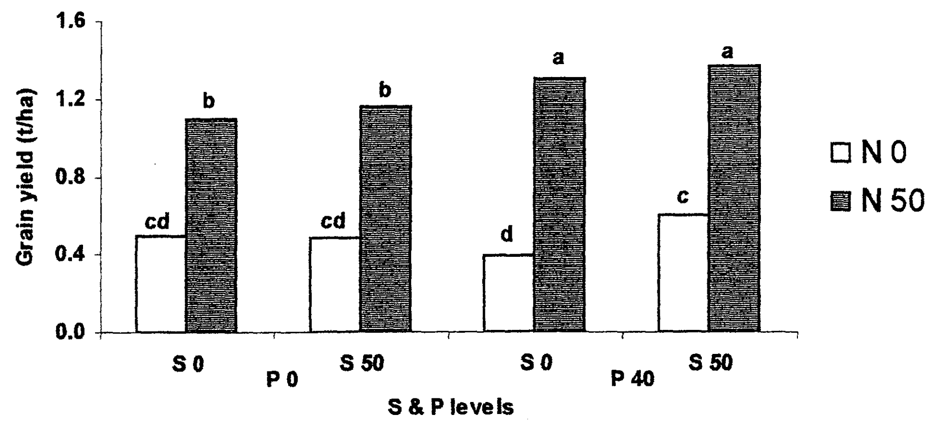

Figure 7.7. Grain yield as affected by the interaction of S x P x N at Coventry.

Data bars labelled with the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

7.3.2. Laureldale site

i) Straw yield

The effects of each individual nutrient (N, P, K and S) at the rate of 50, 40, 50 and 50 kg/ha, respectively were compared to Nil treatment through separate statistical analysis to see the effects of these elements individually (Figure 7.8). It was observed that there was 26% increase in the straw yield over Nil with the application of N alone. The application of P, K and S resulted in the lower straw yields of 14% due to P and 8% each due to K and S over Nil. However, the increase or decreases were statistically non-significant compared to Nil.

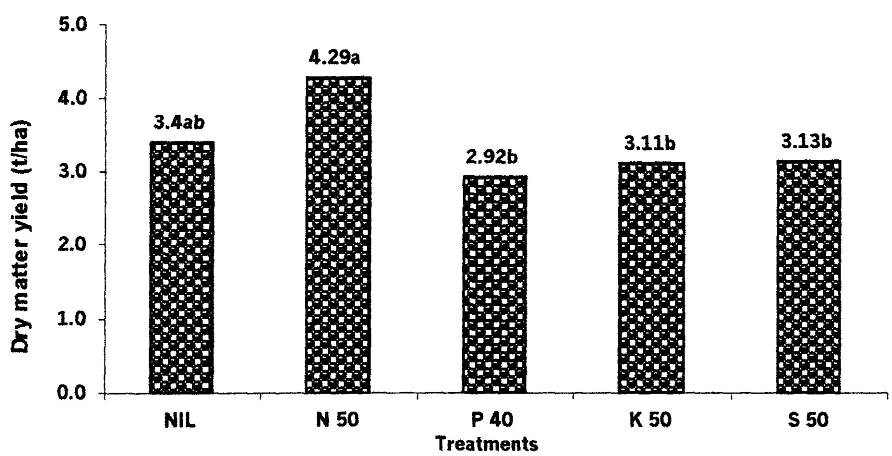

Figure 7.8. Effects of N, P, K, and S on the straw yield in comparison with NIL at Laureldale.

Numbers followed by the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

The data in Table 7.7 represent the straw yield as affected by the main effects of N, P, K, and S at Laureldale soil. The mean values (n=32) were averaged for the two levels of the respective nutrients. Addition of 50 and 40 kg/ha N and P produced significant increases of 26% and 13% in the mean straw yield over N_0 and P_0, whereas the effect of application of 50 kg/ha K and S was non-significant (Table 7.7). These results suggested that straw yield of buckwheat was mainly affected by N and P.

Table 7.7. Average (n= 32) straw yield (t/ha) affected by the application of N, P, K, and S at Laureldale.

Rate	0 kg/ha	50 kg/ha
Nutrients		
Nitrogen	3.19b	4.01a
Phosphorus*	3.38b	3.82a
Potassium	3.69a	3.51a
Sulfur	3.67a	3.53a

Numbers followed by the same letters within a row are not significantly different according to DMRT $P \leq 0.05$.

*Phosphorus (40 kg/ha)

Table 7.8 represent data for the effects of individual treatments where N, P, K, and S were applied alone and in different combinations. The mean values are average of 4 replications per given treatment. The data revealed that addition of N alone and in combination with P, K, and S produced higher straw yield than control and as well as from the corresponding treatments without N (Table 7.8). However, significant increases in straw yield were produced by the treatment of NP, KNP and SNP over P, KP, and SP, respectively.

Table 7.8. Straw yield (t/ha) affected by N, P, K, S, and their interactions at Laureldale.

Treatment	Straw yield (t/ha)	Treatment	Straw yield (t/ha)
NIL	3.40	N	4.29
K	3.11	KN	3.45
S	3.13	SN	3.51
SK	2.66	SKN	3.48
P	2.92	NP	4.28
KP	3.27	KNP	4.65
SP	3.40	SNP	4.60
SKP	3.66	SKNP	3.80

LSD (0.05) = 1.09

ii) Grain yield

The effect of applications of each of N_{50}, P_{40}, K_{50}, and S_{50} were compared to Nil by separate statistical analysis (Figure 7.9). This comparison was made keeping in view the fertiliser application practices by the framers. As compared to Nil, the application of N and P produced non-significant increases of 21% and 5%, while K and S caused a non-significant decrease of 4% and 7%, respectively.

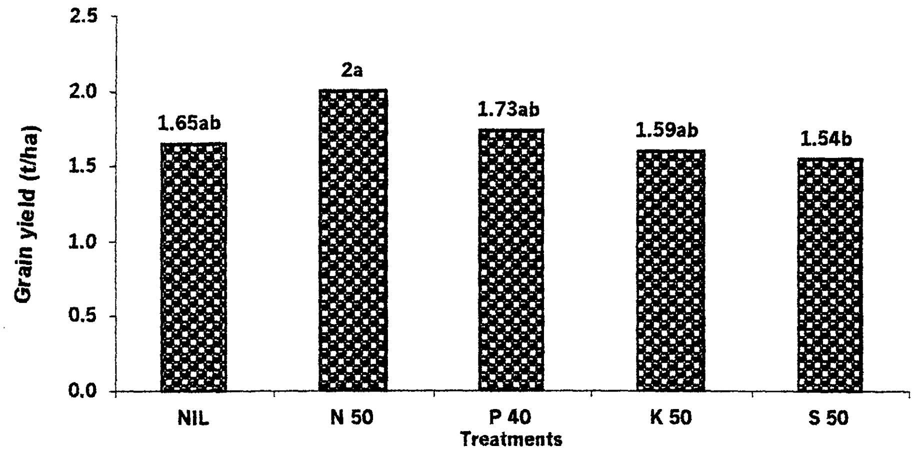

Figure 7.9. Effects of N, P, K, and S on the grain yield in comparison with NIL at Laureldale.
Numbers followed by the same letters within a figure are not significantly different according to DMRT $P \leq 0.05$.

The data in Table 7.9 represent the grain yield (t/ha) as affected by the main effects of N, P, K, and S at Laureldale soil. The mean values (n=32) were averaged for the two levels of the respective nutrients (Table 7.7). Application of N_{50}, increased the grain yield significantly by 15% while P_{40} resulted in a non-significant increase of 10% where as K_{50} and S_{50} caused a non-significant decrease of 11% and 3% over their N_0, P_0, K_o, and S_0 treatments, respectively (Table 7.9). This slightly depressing effect of K and S was also observed in case of straw yield.

Table 7.9. Average (n=32) grain yield (t/ha) affected by the application of N, P, K, and S at Laureldale.

Rate	0 kg/ha	50 kg/ha
Nutrients		
Nitrogen	1.59b	1.83a
Phosphorus*	1.63a	1.79a
Potassium	1.80a	1.62a
Sulfur	1.73a	1.68a

Numbers followed by the same letters within a row are not significantly different according to DMRT $P \leq 0.05$.

*Phosphorus (40 kg/ha)

Table 7.10 represents an average mean values (n=4) for the individual treatments and provide a comparison with control and of the various combinations of N, P, K, and S. Application of N alone produced the highest yield of 2.0 t/ha with a non-significant increase of 21% over control which had a grain yield of 1.65 t/ha. An equivalent increases were produced by the addition of NP (15%), KNP (42.7%), and to some extent with SNP (11%) as compared to P, KP, and SP (Table 7.10). A net significant increase of 0.59 t/ha produced by NPK yielding 1.97 t/ha over the KP treatment where by a yield of 1.38 t/ha was obtained, suggests the synergistic effect of N on K and P. However, the depressing effect of K when applied alone or in combination with S and P is evident from the data.

Table 7.10. Grain yield (t/ha) affected by N, P, K, S, and their interactions at Laureldale.

Treatment	Grain yield (t/ha)	Treatment	Grain yield (t/ha)
NIL	1.65	N	2.0
K	1.59	KN	1.57
S	1.54	SN	1.76
SK	1.46	SKN	1.47
P	1.73	NP	1.99
KP	1.38	KNP	1.97
SP	1.79	SNP	1.98
SKP	1.6	SKNP	1.78

LSD (0.05) = 0.56

It is important to note that chocolate soil which contained 65 mg/kg NO_3-N out-yielded the Coventry soil (<2 mg/kg NO_3-N) by a factor of 5 to 6 in terms of straw yield when no N was added. With addition of 50 kg N/ha alone or in combination with other nutrients reduced this factor by 2-3 times while comparing the straw yields of the two soils. In case of grain yield, the chocolate soil produced an average of 3.2 and 1.45 time higher yield than the Coventry soil for N_0 and N_{50}, respectively. This observation indicates the pronounced response of Coventry soil to addition of N, which was severely N deficient.

7.4. DISCUSSION

The chemical analysis (Table 7.2) of the Coventry site (yellow podsolic soil) indicated that it was severely deficient in N (< 2 mg/kg). As a result of this low fertility, the application of N fertiliser significantly influenced the yields up to 121%. The results of the current study indicated that an application of N at the Coventry site (yellow podsolic soil) is essential for good yield. These results are in agreement with the findings of Kreindler (1960); Trusova *et al.,* (1976); Fatyga (1986); and Narian (1983) on similar N deficient soils.

The P level in the soil is deficient (6 mg/kg) on the basis of P requirement of oat, wheat and barley (Soil Interpretation Mannual, 1990). The application of P alone and with S and K did not produced any changes in yield when compared with Nil (Table 7.4, Fig 7.1). However, addition of P increased straw and grain yields over P_0 when data were averaged across N, K, and S (Table 7.3). This clearly indicated the additive effects of N and P on the yield of buckwheat. This additive effect was absent with S and K, which means that N was the key yield limiting factor. This observation is supported by the close analysis of yield data (Table 7.4 and 7.6) which indicated that increases in yield were obtained mainly with the addition of N which were further improved where S and P were applied with N.

The lack of yield response in the absence of other major nutrients can be explained through the Liebig law of minimum "every field contains a maximum of one or more and minimum of one or more nutrients". With this minimum be it N, P, K, Mg or any other nutrient, the yields stand in direct relation. It is the factor that governs and controls yield. In the case of Coventry soil, containing <2 mg/kg NO_3-N, meaning that the minimum was N, yield virtually remained the same with the addition of K, S, and P but it increased in proportion to addition of N. According to this theory, in the absence of N which is a limiting factor, the yield can not be increased with mere addition of P. The added advantage can only be obtained if all the essential elements are available at optimum levels. Therefore, the growers are encouraged to supply all demonstrated nutrient deficiencies in fertiliser applications. Narian (1983) observed low response of P in the absence of N on the buckwheat in his study using a light coloured sandy loam soil in India. Similar results with the buckwheat were observed by Kreindler (1960) on a grey brown podsolic soil in Pennsylvania, USA.

Although Coventry site was low in available S (4 mg/kg), its application did not have any beneficial effect on the yield. The behaviour of S in this soil as observed in various results suggests that S response is also dependent on the nitrogen status. The application of S alone in any amount may not be profitable on such soils where N and P are deficient.

The application of K on the same soil did not affect yield significantly in the current study even though the soil was deficient in K content (0.16 meq/100g) according to the requirements of wheat, oats and barley (Soil Interpretation Mannual, 1990). The response to K was not significant in the presence of N but was better than K applied alone. Furthermore, the combined effect of N, P, and K was much better than K, KP, and SKP (Table 7.4 and 7.6). The results from the current study suggest that the application of K alone will not be advantageous for the yield of buckwheat on the same soil conditions. Similar results were reported by Kreindler (1960) on a similar type of soil. Ogiso *et al.*, (1989) reported no response to K fertilisers on a medium textured soil in Japan. Although K did not show any beneficial effect on the yield of buckwheat, it can not be ruled out as a non-essential nutrient for the buckwheat production on the basis of these findings. The application of K may be beneficial for the optimum production in the long term cultivation of buckwheat in this region.

A single rate of N_{50}, P_{40}, K_{50}, and S_{50} kg/ha was applied during the current studies. The application of lower and higher rates of these nutrients are required to be tested in the future studies for choosing the correct levels of each element for the optimal production of buckwheat under different conditions.

The soil analysis at Laureldale site (chocolate soil) indicated that it contained 65, 61, 156, and 7 mg/kg NO_3-N, P (Colwell), K and sulfate-S, respectively (Table 7.2). According to the Soil Interpretation Mannual (1990) the major difference between the Laureldale (chocolate) soil and the Coventry (yellow podsolic) soil was in terms of their differences and the initial level of nutrients and their yield potentials. The chocolate soil produced 5-6 times greater straw yield than Coventry soil in the absence of any N but when N was added, the magnitude of this difference was lowered to 2-3 times. Although, the chocolate soil containing higher NO_3-N level than the Coventry soil, because of its high yield potential it responded positively to the addition of N_{50} producing non-significant increases over control and some of the other nutrients when applied alone. The beneficial effect of N was maximum when applied as NPK and SNP whereby maximum straw yield of 4.65 and 4.60 t/ha was obtained with these treatments, respectively which were significantly higher than the yield of 3.40 t/ha obtained at Nil (Table 7.8).

Given the P (Colwell) status of the chocolate soil (61 mg/kg), the lack of response to the addition of P alone or with K and S is understandable. As mentioned earlier this soil having high yield potential improved the straw and grain yield when P was applied in combination with N. This increase in straw yield was further improved with NPK and SNP. The results suggested that the application of P would be advisable in combination with other major nutrients for the optimum yield of buckwheat.

The Laureldale soil contained 7.0 mg/kg (KCl-40), and 15 mg/kg (MCP) sulfate-S (Table 7.2). It is difficult to decide about the adequacy or deficiency of these levels based on the Soil Interpretation Mannual (1990). Since the addition of S alone or in combination with K and P and even with N did not increase the straw and grain yield of buckwheat. It can be concluded from these results that either this soil provided sufficient S to buckwheat and or the amount applied (50 kg S/ha) was not enough to increase the yield (Soil Interpretation Mannual, 1990). Therefore, further investigations are required to establish the levels of S in combination with N, P, and K for the optimum production of buckwheat.

The concentration of K in this soil was adequate for different crops and further application of this nutrient did not cause any profitable increases in the yield rather a depressing effect on the yield was noted when K was applied alone or in combination with S, P, and N. The only beneficial effect was observed when applied as KNP at the given level of each nutrient. The non-significant but consistent depressing effect of K in this soil could be associated with its adverse effect on the uptake of other cations such as Ca, Mg, and NH_4 (Tisdale, *et al.* 1985 and Mengal and Kirkby, 1987).

Due to high fertility and favourable soil physical conditions (e.g. granular structure, high water holding capacity and well decomposed organic matter) of the Laureldale site, the yields were higher by 200-300% in case of grain and 400-500% in case of straw than the Coventry soil. It is evident from the results of this study that buckwheat gave high productivity on heavy and fertile soils compared to light soils. The findings of the current study are supported by Ruszkowski and Zebrowski (1982), who reported that buckwheat productivity was higher when grown on a heavy soil rather than light soil.

The available nutrient status of the soils changes from time to time due to nutrients leaching, fixation and removal by the plants. It is imperative to have knowledge of the soil nutrient status before the application of any fertiliser for the cultivation of any crop, particularly buckwheat.