RESPONSE OF WHEAT TO SOIL APPLICATION OF NITROGEN AND SULPHUR[1]

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ABSTRACT - A pot experiment was conducted with clay loam alkaline (calcarous) soil from the University of Udaipur Agronomy farm in Rajasthan, India to determine the effects of varying nitrogen and sulphur applications on two wheat varieties at different stages of growth. One hundred kg/ha of nitrogen and 150 to 225 kg/ha of sulphur were found to be the optimum doses under all growth stages. Variety V_1 (HD 2009 - *Triticum aestivum*) was found to be superior to V_2 (HD 4519 - *Triticum durum*) on all characters studied, including chemical composition, with the exception of test weight. Total nitrogen and sulphur accumulation in the plant increased almost linearly until maturity. Thus, in a fertilization program it would be important to have an adequate supply of nitrogen and sulphur throughout the growing season. Application of nitrogen resulted in increased plant levels of phosphorus, calcium and sulphur. Sulphur application did not affect plant levels of calcium and phosphorus; however, nitrogen content did increase as sulphur application increased. In order to support satisfactory plant growth and development, the soil used in this study must be able to sypply at least 1.5 to 4 mg of nitrogen per plant per week within the growth period of 55 to 135 days, and 1.3 to 3.5 mg of sulphur per plant per week during the same period.

Index terms: sulphur deficiency, rate of nutrient uptake, plant composition, effective root area.

RESPOSTA DO TRIGO A NITROGÊNIO E ENXOFRE APLICADOS AO SOLO

RESUMO - Foi conduzido, em casa de vegetação, um experimento com solo limo-argiloso alcalino da Fazenda Agronomia, da Universidade de Udaipur, Rajasthan (India), para determinar os efeitos de vários níveis de nitrogênio e enxofre na produção e componentes de produtividade, e composição química das plantas de duas variedades em diferentes estádios de crescimento. Cem kg/ha de nitrogênio e 150 a 225 kg/ha de enxofre foram as doses ótimas para estas condições. A variedade V_1 (HF 2009 - *Triticum aestivum*) foi considerada superior a V_2 (HG 4519 - *Triticum durum*) em todas as características estudadas, como, por exemplo, composição química das plantas, exceto peso de 1000 sementes. Nitrogênio e enxofre acumulados em toda planta aumentaram quase linearmente até a maturação. Portanto, seria importante que o programa de fertilização tivesse um adequado suplemento de nitrogênio e enxofre em todo o ciclo de crescimento do trigo. A aplicação de nitrogênio aumentou o fósforo, cálcio e enxofre na planta. A aplicação de enxofre não afetou a concentração de cálcio e fósforo na planta, mas o nitrogênio da planta foi aumentado na medida em que aumentava a aplicação de enxofre. Para a planta ter um crescimento satisfatório, o solo estudado deve ser capaz de fornecer 1,5 a 4 mg de nitrogênio/planta por semana entre 55 a 135 dias de idade. Para o enxofre, a planta precisa de 1,3 a 3,5 mg/planta por semana para a mesma idade.

Termos para indexação deficiência enxofre, taxa de abasorção de nutrientes, composição química da planta, área efetiva de raiz.

INTRODUCTION

Sulphur has long been recognised as an essential element for plant growth (Gilbert 1951). Its role in the formation of aminoacids in plants is well established. In this role the metabolism of sulphur is closely related to that of nitrogen. Sulphur could gradually become a yield limiting factor with an increasing in crop yields, together with an increased use of nitrogen fertilizers and with a reduction in the use of sulphur containing fertilizers. Therefore, in many situations the study of one of these elements requires the concurrent study of the other.

Various studies of the effects of nitrogen and sulphur on small grains such as oats, barley and wheat have been reported (Crofts & Blair 1966, Eppendorfer 1968, Nielson et al. 1967, Reisenauer & Dickson 1961 and Stewart & Porter 1969). The relationship of nitrogen and sulphur on corn (*Zea mays* L) has been studied by Mamaril & Miller (1970), Rehm & Caldwell (1970). It is

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concluded from these studies that the effects of nitrogen and sulphur on crop growth vary widely, depending on the crop grown and the type of soil on which it is grown.

The interactions and the interrelations among the various nutrients taken up by the plants are not completely understood. For example nitrogen is expected to reduce phosphate uptake as reported by Wit et al. (1963), but Cole et al. (1963), Brown & Jones (1974) reported stimulation by nitrogen application. Similarly, Fujiwara & Torri (1961) reported a higher sulphur content in plants receiving NO_3-N application, but Welch et al. (1954) observed that an increase in the NO_3 concentration in solution produced a decrease in the uptake of sulphur and phosphorus. Therefore, the present investigation was undertaken with the following objectives:

1. To compare two wheat varieties in regard to their response to added nitrogen and sulphur.
2. To clarify the relationship between nitrogen and sulphur uptake under several nitrogen and sulphur fertilization levels.
3. To descover the uptake patterns of phosphorus and calcium under different nitrogen and sulphur levels of two varieties.

MATERIALS AND METHODS

A pot experiment was conducted during the 1973/74 growing season. The soil used in this experiment was taken from the University of Udaipur Agronomy Farm, Udaipur, India. Some physical and chemical properties of the soil are: coarse sand 11.3%; fine sand 33.5%; silt 21.6%; clay 33.6%; total nitrogen 0.07%; available phosphorus 13 kg/ha; available potassium 145.7 kg/ha; cation exchange capacity 13.6 meq/100 g of soil and pH 8.4. The soil was dried and screened, and 5 kg were weighed into each pot of 22.5 cm size. The four levels of sulphur were applied 21 days before sowing at the rate of 0; 75; 150, and 225 kg/ha of elemental sulphur. Since elemental sulphur becomes available to plants after its oxidation to a sulphate (Li & Caldwell 1966), early application permitted oxidation to occur before planting. Four doses of nitrogen i.e. 0; 50; 100, and 150 kg/ha were applied as NH_4NO_3 in three fractional doses to minimize nitrogen losses and to provide a continuous supply of nitrogen to support proper growth and nutrition of the wheat plant (Spratt 1974). Half of the dose was applied at sowing time, 1/4th one month after sowing and the remainder at 50 days of growth. A basal dose of 40 kg/ha of potassium as potassium chloride and 60 kg/ha of phosphorus as phosphoric acid was applied. All the fertilizers were thoroughly mixed with the soil. Each treatment was replicated five times with the fourth and fifth replications sacrificed at 55 and 100 days growth for chemical analysis.

Wheat was used as the test crop, and eight seeds per pot of varieties V_1 (HD 2009) and V_2 (HD 4519) were sown on 7th November, 1973. After germination the plants were thinned to five per pot. All pots were irrigated with ordinary tap water and soil moisture was maintained at approximately 0.3 atm. during the growth period. The crop was harvested on 22nd March, 1974, and grain yield and ancillary characters were recorded. Plants from two additional replications were harvested on 2nd January and 15th February, 1974. Plant material was dried in an oven at 75°C 36 hours. Predried material were weighed and ground in a Wiley Mill for chemical analysis. The powdered plant samples were analised for total nitrogen by the method of Linder (1944); phosphorus by ammonium-vanadate-molybdate yellow color (Estados Unidos. Department of Agriculture, 1973); calcium by the method described by Jackson (1958); and sulphur turbidimatric as suggested by Tabatabai & Bremner (1970).

RESULTS AND DISCUSSION

The data for plant growth, yield components as influenced by varieties, and nitrogen and sulphur levels are presented in Table 1. A perusal of data in Table 1 indicates that variety V_1 proved to be superior to V_2 in respect to growth, yield and yield attributing characters, with the exception of test weight which was higher for the V_2 variety. V_1 produced a 27.7% higher grain yield than V_2. Data in Table 1 shows that increasing levels of nitrogen resulted in increased plant height, number of tillers, length of ear, test weight and yield of grain as well as straw. Similarly, increasing doses of sulphur also had beneficial effects in respect to yield attributing characters.

Correlation coefficients and regression equations between yield; test weight and height were calculated for nitrogen and sulphur treatments. Correlation coefficients between test weight and yield were: 0.316 and 0.977 under nitrogen and sulphur treatments respectively, while 'r' values height and yield were 0.448 and 0,677 under these two treatments. The regression equations for test weight and yield for nitrogen and sulphur were: $\hat{Y}$ = 4.96 + 0.83X and $\hat{Y}$ = -16.74 + 0.63X

TABLE 1. Plant growth and yield components under different treatments.

Treatments	Plant height (cm)	Nº of tillers per plant	Length of ear (cm)	Test wt. (g)	Grain yield (g/pot)	Straw yield (g/pot)
V_1	32.98	2.35	8.38	36.36	9.25	9.83
V_2	30.37	2.05	4.60	42.69	7.24	9.06
S.Ed. ±	0.33	0.21	0.10	0.42	0.30	0.25
C.D. at 5%	N. S.	0.42	0.20	0.84	0.60	0.50
N_0	30.53	2.08	6.30	39.18	7.90	8.89
N_1	31.46	2.23	6.40	39.63	8.23	9.54
N_2	32.11	2.24	6.60	39.80	8.40	9.67
N_3	32.61	2.25	6.62	39.82	8.45	9.70
S.Ed. ±	0.47	0.30	0.30	0.59	0.59	0.35
C.D. at 5%	0.95	N. S.	0.29	N. S.	N. S.	N. S.
S_0	30.68	2.05	6.20	37.91	7.25	8.95
S_1	31.81	2.20	6.50	39.82	8.34	9.60
S_2	32.05	2.27	6.60	40.09	8.46	9.63
S_3	32.17	2.28	6.70	40.28	8.92	9.60
S.Ed. ±	0.47	0.30	0.14	0.59	0.42	0.35
C.D. at 5%	0.95	N. S.	0.29	1.19	0.85	N. S.

N.S.= Not significant

respectively, whereas the equations between height and yield under these treatments were $\hat{Y} = -0.35 + 0.27X$ and $\hat{Y} = -45.84 - 1.70X$ respectively. Regression equations were also worked out for different treatments of N and S with respect to yield. They were: $\hat{Y} = 7.972 + 0.0036X$ and $\hat{Y} = 7.437 + 0.0068X$ respectively.

Plant composition

Chemical composition of the plants may be of interest to establish some possible interference of different nutrients in the uptake process. Successful management also requires the supplying of the correct amount of nutrients to the plants at a time when they can best use them. This means we need basic plant physiological knowledge on the nutrient requirements of plants at various stages of growth. Therefore, the concentration of nitrogen, calcium, phosphorus and sulphur in the plants under different growth stages are determined. Under all the treatments the per cent content of N, P, Ca and S were decreased with the advancement of age (T. 2,3). The decrease in content of these elements with the advancement of the age may be due to higher rate of accumulation of drymatter than the rate of uptake of these elements. In other words it can be explained as dilution effects. The results are in agreement with those reported by Fageria (1973), Harper (1971), and Carter et al. (1971).

With respect to N, P, Ca and S contents, V_1 was superior to V_2. This may be due to difference in genetic make of these varieties. Nitrogen and sulphur content increased with increasing doses of these elements and followed a hyperbolic curve as might be expected. Sulphur application increased the nitrogen content in the plants (Table 2) under all stages of crop growth. Similarly with the increasing nitrogen application, there was an increase in sulphur content of the plants. This reciprocal synergistic effect of nitrogen and suphur is generally considered to be the result of a stimulated anion intake in response to an overall increase in cation uptake. This is in ageement with the findings of other workers (Reisenaur & Dickson 1961, Rehm & Caldwell 1970).

Nitrogen application increased the phosphorus content in the plants. This increase in phosphate uptake may be attributed to the effect of nitrogen on the physiological process that controls the uptake of phosphorus (Grunes et al. 1958). Ac-

TABLE 2. Drymatter, N and P contents of wheat at three growth stages.

Treatments	Days 55	After 100	Sowing 135
		Drymatter g/plant	
V_1	0.19	0.94	1.96
V_2	0.17	0.90	1.81
N_0	0.18	0.89	1.78
N_1	0.24	1.00	1.91
N_2	0.26	1.20	1.93
N_3	0.25	1.23	1.94
S_0	0.20	0.90	1.79
S_1	0.25	1.06	1.92
S_2	0.26	1.16	1.93
S_3	0.26	1.20	1.92
		%N	
V_1	1.18	0.80	0.55
V_2	1.09	0.75	0.40
N_0	1.15	0.65	0.50
N_1	1.40	1.02	0.80
N_2	1.50	1.14	0.92
N_3	1.56	1.20	1.05
S_0	1.09	0.70	0.50
S_1	1.18	0.93	0.70
S_2	1.25	1.00	0.78
S_3	1.30	1.05	0.81
		%N	
V_1	0.36	0.29	0.20
V_2	0.30	0.20	0.16
N_0	0.16	0.15	0.14
N_1	0.25	0.22	0.17
N_2	0.30	0.26	0.17
N_3	0.33	0.28	0.18
S_0	0.20	0.16	0.13
S_1	0.22	0.18	0.17
S_2	0.23	0.19	0.18
S_3	0.23	0.19	0.17

TABLE 3. Calcium and sulphur contents of wheat at three growth stages.

Treatments	Days 55	After 100	Sowing 135
		%Ca	
V_1	0.52	0.42	0.32
V_2	0.48	0.38	0.30
N_0	0.38	0.31	0.22
N_1	0.50	0.37	0.30
N_2	0.56	0.40	0.34
N_3	0.60	0.39	0.36
S_0	0.40	0.30	0.24
S_1	0.41	0.29	0.26
S_2	0.38	0.33	0.22
S_3	0.42	0.28	0.23
		%S	
V_1	0.15	0.08	0.06
V_2	0.13	0.07	0.05
N_0	0.09	0.08	0.05
N_1	0.13	0.09	0.08
N_2	0.15	0.11	0.09
N_3	0.16	0.12	0.10
S_0	0.09	0.07	0.05
S_1	0.14	0.09	0.07
S_2	0.15	0.10	0.08
S_3	0.15	0.11	0.08

cording to Thien & McFee (1970) there may exist a nitrogen requiring metabolite which is essential to phosphorus movement in toot cells but which is restricted to bilateral intercell movement. Such a carrier might be mobile within parent cell and the symplastic system leading to the xylem, thus accounting for the rapid lateral movement necessary for rapid translocation. Support for this type of behavior comes from the work of Livingston (1935), who counted the number of plasmadesmata in tobacco (*Nicotiana tabacum*) cells and found up to 24 threads per 100 square microns in the end walls and only 7 to 9/100 square microns in the side walls. Such an arrangement may help to explain why nitrogen and phosphorus must be closely associated when the external movement of nutrients is restricted as in soils. Phosphorus content was independent of sulphur application.

With increasing nitrogen concentration in the root medium, the calcium content in the plants increased. The increase in calcium with increased nitrogen can be attributed to reduced competition in the absorption process (Cox & Reisenauer 1973). Increases in calcium content with application of nitrogen were also reported by Bar-Yosef & Kafkafi (1974) in maize plants. Increased doses of sulphur have no effect on calcium content in the plants.

Rate of nutrient uptake

Because of the dynamic nature of the nutrition process, the plants demands are expressed in terms of flux (F), as described by Bar-Yosef & Kafkafi 1972):

$$F_i = \frac{(\Delta Q)\, i}{ERA_i\, \Delta t}$$

where ΔQ is the quantity absorbed (g/plant), Δt is a constant time interval (sec), ERA is the effective root area (cm^2/plant), and i, is an index of time intervals.

The effective root area (ERA) of the wheat was calculated by the following formula as described by Bar-Yosef & Kafkafi (1970) and based on the same assumptions.

$$ERA_{(i)} = \frac{(\text{uptake of Ca})\, i}{\text{Flux of Ca}} = \frac{\text{mg/plant/week}}{\text{mg/cm}^2\text{/week}} = \frac{\text{cm}^2}{\text{plant}}$$

In this study, maximum uptake rate value ($\Delta Q/ \Delta t$) for nitrogen and phosphorus was calculated between time intervals of 55-100 and 100 to 135 days using the above formula and data in Table 1. The uptake rate values ($\frac{\Delta Q}{\Delta t}$) for nitrogen at optimum dose (100 kg/ha) were found to be 1.53 mg/plant week for 55-100 days and 4.07 mg/plant/week for 100-135 days of growth respectively. For sulphur it was 1.3 to 1.45 mg/plant/week for 55-100 days and 2.95-3.45 mg/plant/week for 100-135 days of growth. These flux values can be used as a guide line in fertilization of field crops for maximizing crop production.

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