

Research Article

Interactive Effects of Nitrogen and Sulfur on Growth, Dry Matter Partitioning and Yield of Maize

Amanullah, Shah Fahad Bashir, Abdul Qahar*, Shahen Shah, Bashir Ahmad and Asif Iqbal

Department of Agronomy, Faculty of Crop Production Sciences, the University of Agriculture, Khyber Pakhtunkhwa (KPK), Peshawar, Pakistan

*Corresponding author's email: abdul.qahar@aup.edu.pk

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Abstract

Nitrogen (N) and sulfur (S) are important crop nutrients limiting the crop growth and yield. In order to study N and S effect on growth, dry matter partitioning and grain yield of maize, a field experiment was conducted at the New Developmental Research Farm of Khyber Pakhtunkhwa (KPK), The University of Agriculture, Peshawar during summer 2011, which was designed in randomized complete block design (RCBD) replicated thrice. Growth, dry matter partitioning, yield & yield components, and harvest index responded positively to N and S fertilization, but the magnitude of response varied with level of N and S application. Days to tasseling, silking and physiological maturity delayed, plant height and mean single leaf area increased with increase in N and S levels. Similarly, dry matter partitioning in stem, leaf, ear, and grains was increased with an increase in N and S levels and decreased in the control plots. The heaviest thousand grains weight was obtained when both N and S were applied at the highest rates. The highest grain yield *viz.*, 3122 kg ha⁻¹ was obtained in the plots where N was applied @ 160 kg ha⁻¹, while minimum grain yield *i.e.* 2039 kg ha⁻¹ was obtained in control plots. Grain yield increased to maximum (2882 kg ha⁻¹) when S was applied @ 40 kg ha⁻¹, and the lowest grain yield (2458 kg ha⁻¹) was recorded in control plots. The harvest index ranked first when both N (27.8%) and S (27.7%) were applied at the highest rates of 160 kg N and 40 kg S ha⁻¹. Harvest index showed positive relationship with the increase in grain yield and yield components in maize. The results indicated that all the three levels of N and two levels of S increased the yield components and grain yields as well as harvest index in maize, and increased with an increase in N and S levels when compared with the control (N and S not). It is therefore, suggested that application of the highest S @ 40 kg S ha⁻¹ and N levels @ 160 kg N ha⁻¹ could increase maize productivity in the study area.

Key words: Maize, nitrogen and sulfur fertilization, yield components.

Introduction

Maize (*Zea mays* L.) is a multipurpose crop that provides food for human, feed for

animals especially poultry and livestock. It is a rich source of raw material for the industries where it is being extensively used

for the preparation of corn starch, corn, dextrose, corn syrup and corn flakes [1]. It is the third most important summer cereal in Pakistan, after wheat and rice. In the farming system of Khyber Pakhtunkhwa (KPK) maize is 2nd to wheat in its importance. During 2008-2009, maize grown on an area of 1.01 million hectares of land with total production of 3.08 million tones and national average yield of 3037 kg ha⁻¹ in Pakistan, whereas in KPK under maize crop area was 509457 hectares and production was 957897 tones with an average yield of 1780 kg ha⁻¹ [2, 3]. The yield obtained from maize in Pakistan is very low as compared to other country due to many constraints. These include poor quality seed, indiscriminate application of fertilizers without soil testing, poor tillage methods and lack of modern technology. Among all the crop plants, maize is the most versatile one as it has great nutritive value 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 17% ash [4].

Nitrogen (N) and sulfur (S) plays an important role in good and economic yield of maize crop. S is considered to be sometimes forgotten secondary nutrient in crop production. However, it is very essential for the synthesis of amino acids and activity of proteolytic enzymes. The real importance of S has been marked in the recent past due to intensive cultivation with high yielding varieties and the use of complex fertilizers, which led to S deficiency in many farm soils [5].

S has specific functions during plant growth, metabolism, and enzymatic reactions [6]. Sulfur is required for the synthesis of sulfur-containing amino acids such as cystine, cysteine, and methionine. Sulfur is also a constituent of S-glycosides (mustard oils), coenzymes-A, vitamin biotin, and thiamine [7]. Sulfur is related to the formation of oil particularly in oil-producing crops. A deficiency of S causes plants to be

uniformly chlorotic, stunted, thin stemmed, and spindly. Keeping in view the significant role of N and S in maize crop production, the current experiment was designed to study and recommend optimum nitrogen and sulfur levels for attaining maximum yield of maize crop in the study area.

Materials and Methods

An experiment was conducted at New Developmental Farm, The University of Agriculture Peshawar Pakistan, during the summer 2011. The experiment was laid out in RCBD (randomized complete block design) with three replications. Plot size was 15 m² (5 x 3 m²) consisting of five rows, 5 m long and 75 cm apart. Sulfur (S) was applied in the form of ammonium sulphate, while nitrogen (N) was applied in the form of urea.

The experiment included the following factors and their levels:

Factor A: Nitrogen levels (0, 80, 120, 160 kg ha⁻¹).

Factor B: Sulfur levels (0, 20, 40 kg ha⁻¹).

Days to tasseling was recorded by counting number of days from sowing to the date on which 80% plants produce tassels likewise days to silking. Days to physiological maturity was recorded from sowing till 80% plants become physiologically mature as the seeds show a black layer formation at the base of the seed. Plant height for all treatments in each replication was measured with the help of a measuring tape from the base to tassel tip of the ten randomly selected plants and then average plant height was calculated. Biological yield was recorded by weighing plants harvested from two central rows of each plot and then converted into kg ha⁻¹. The ear harvested for grain yield was used for the determination of number of grains per ear by selecting five ears randomly from each subplot, dried and shelled for counting the grains cob⁻¹. Data regarding 1000 grains weight was recorded by counting actual number of 1000 grains at

random and then was weighed with electronic balance. Grains yield was recorded after shelling of ears of two central rows from each subplot and was converted into kg ha⁻¹. Harvest index was calculated according to the following formula:

$$\text{Harvest Index} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

At physiological maturity 10 plants were randomly harvested from the three central rows. Leaves, stem, ears, grains and sheaths were separated, dried and weighed to record data on dry weight of leaf, stem, ear, grains and sheath. Dry weight plant⁻¹ at physiological maturity was calculated as sum of the dry weights of the plant components. Number of leaves plant⁻¹ was counted in the 10 plants and the average was worked out. The leaf length and width of the five middle leaves was measured and the average length and width was calculated. Then single leaf area was calculated.

Statistical analysis

Data was statistically analyzed and means was composed using LSD test ($P \leq 0.05$) [8].

Results and Discussions

Days to tasseling

Statistical analysis of the data indicated that N and S levels had significant effects while their interaction had non-significant effects on days to tasseling (Table 1). Among N levels, days to tasseling was delayed to 51.3 days when N was applied @ 160 kg ha⁻¹, followed by 51.0 days with 120 kg N ha⁻¹, while the earliest tasseling (50.0 days) was recorded in control (N not applied). Delay in days to tasseling was observed with increase in N rate [9]. Among S levels, days to tasseling was delayed to 51.1 days when S was applied @ 40 kg ha⁻¹, while the earliest tasseling (49.9 days) was noted, when no S was applied. The probable reason for this could be that N and S meets the nutritional

requirement of crop and hence enhanced vegetative growth and delayed tasseling [10].

Days to silking

Analysis of variance (ANOVA) of the data showed that N and S had significant effects on days to silking, while their interaction had non-significant effects. Days to silking was delayed to 54.8 days when N was applied @ 160 kg ha⁻¹, followed by 54.3 days with 120 kg ha⁻¹, while the earliest silking (52.4 days) was recorded in control plots. Delay in days to silking in maize was observed with increase in N rate [9, 10]. Days to silking was delayed to 54.3 days when S was applied @ 40 kg ha⁻¹, while the earliest tasseling (53.0 days) was noted when S in control plots. The probable for reason might be that nitrogen being a part of amino acids increased protein formation and hence improved vegetative growth and delayed days to silking likewise in tasseling [11].

Days to physiological maturity

N and S levels had significant effect on days to physiological maturity, while maturity was delayed to 88.6 days in the plots were N was applied @ 160 kg ha⁻¹, followed by 88.2 days with 120 kg ha⁻¹. The earliest days to physiological maturity (85.8 days) was recorded in control plots. Delay in days to physiological maturity was observed with increase in N rate. Days to physiological maturity was delayed to 88.3 days, where S was applied @ 40 kg S ha⁻¹, while early physiological maturity of 86.7 days was recorded in control plots. This might be due to the fact that both macro nutrients (N and S) enhanced biochemical processes and hence delayed days to physiological maturity [10, 11].

Plant height (cm)

N and S had significant effect on plant height, while there interaction had non-significant effect on plant height in maize (Table 1). Maximum plant height (234.5 cm)

was obtained in the plots where N was applied @ 120 kg ha⁻¹, while minimum plant height (212.4 cm) was recorded in control plots. Organic and inorganic sources of N application increased plant height in maize than control [12]. Among S levels, the highest plant heights (230.7 cm) was obtained in the plots where S was applied @ 40 kg ha⁻¹, and plant height reduced to minimum (216.1 cm) in plots where no S was applied. The increase in plant height due to S application probably may be due to the increase in N uptake that may have positive influence on plant height in maize [12].

Mean single leaf area (cm²)

Statistical analysis of the data indicated that N and S levels had significant effects on leaf area, while their interactions had non-significant effects on leaf area (Table 1). Among N levels, maximum leaf area was recorded (485.74 cm²) in the plots where N was applied @ 120 kg ha⁻¹, followed by (478.4 cm²) with 160 kg ha⁻¹, while the lowest leaf area (449.8 cm²) was noted in control plots. Among S levels, leaf area was high (474.2 cm²) when S was applied at the highest rate of 40 kg S ha⁻¹, while the lowest leaf area (449.8 cm²) was noted when S was not S applied [12].

Stem dry weight plant⁻¹ (g)

Statistical analysis of the data indicated that N and S levels had significant effects on stem dry weight plant⁻¹, whereas N x S had non-significant effect on stem dry weight plant⁻¹ (Table 1). Among N levels, maximum stem dry weight plant⁻¹ was recorded (43.4 g) in plots where N was applied @ 160 kg N ha⁻¹, followed by (42.2 g) with 120 kg ha⁻¹, while minimum stem dry weight plant⁻¹ (38.2 g) was recorded in control plots. Dry matter increased linearly with an increase in N application [12, 13]. Among the S levels, stem dry weight plant⁻¹ was high (42.6 g) when S was applied at the highest rate of 40 kg ha⁻¹, while the stem dry

weight plant⁻¹ was minimum (39.5 g) in the plots where S was not applied (control). Dry matter components of maize were significantly enhanced with the application of S compared with control [13].

Leaf dry weight plant⁻¹ (g)

N and S levels had significant effects on leaf dry weight plant⁻¹, while N x S had non-significant on leaf dry weight plant⁻¹ (Table 1). Maximum leaves dry weight plant⁻¹ (33.1 g) was obtained in the plot where N was applied @ 160 kg ha⁻¹, while minimum leaf dry weight plant⁻¹ (26.7 g) was obtained in control plots. Dry matter increased linearly with increase in N application. Among S levels, the highest leaf dry weight plant⁻¹ (31.5 g) was obtained in plots where S was applied @ 40 kg ha⁻¹, and the lowest leaf dry weight plant⁻¹ (29.0 g) was recorded in the plots where S was not applied. Dry matter components of maize were significantly enhanced with the application of S compared with control [13].

Ear dry weight plant⁻¹ (g)

Statistical analysis of the data showed that N and S levels and its interaction had significant effects on ear dry weight plant⁻¹ (Table 9). Maximum ear dry weight plant⁻¹ (132.0 g) was obtained in the plots where N was applied @ 120 kg ha⁻¹, while minimum ear dry weight plant⁻¹ (93.0 g) was obtained in control plots. Dry matter increased linearly with increase in N application [13]. Among S levels the highest ear dry weight plant⁻¹ (383.8) was obtained in the plot where S was applied @ 40 kg ha⁻¹, while the lowest ear dry weight plant⁻¹ (341.8) was recorded in control plots. Dry matter partitioning in maize were significantly enhanced with the application of S compared with control [14].

Thousand grains weight (g) Statistical analysis of the data indicated that N and S levels had significant effects on thousand grains weight while their interaction had non-significant effects (Table 14).

Table 1. Days to tasseling, silking, physiological maturity, mean single leaf area, stem, leaf, ear dry weight, thousand grain weight, grain yield and harvest index of maize as affected by different levels of nitrogen and sulfur.

Nitrogen (kg ha ⁻¹)	Days to tasseling	Days to silking	Days to Physiological Maturity	Plant height(cm)	Mean Single Leaf Area(cm ²)	Stem dry weight plant ⁻¹ (g)	Leaf dry weight plant ⁻¹ (g)	Ear Dry Weight(g)	000 Grain weight(g)	Grain Yield (kg/ha)	Harvest Index (%)
0	50	52	86	212.4	403.6	38.22	26.74	93.9	222.67	2039	21.69
80	50	53	87	219.5	475.4	40.59	30.37	126	226.89	2705	27.65
120	51	54	88	234.5	485.7	42.22	31.11	137.7	228.33	2969	26.83
160	51	55	89	230.5	478.4	43.41	33.11	132	228.44	3122	27.83
Lsd Value(0.05)	0.59	0.87	0.80	4.70	11.43	1.23	1.37	2.50	4.05	149	2.04
Sulfur (kg ha⁻¹)											
0	50	53	87	216.1	449.8	39.56	29	113.9	222.58	2458	25.78
20	51	53	87	225.9	458.4	41.11	30.44	125.3	228	2786	24.52
40	51	54	88	230.7	474.2	42.67	31.56	127.9	229.17	2882	27.7
Lsd Value (0.05)	0.51	0.76	0.69	4.1	9.9	1.06	1.17	2.2	3.05	129	1.76
Interaction											
N x S	ns	Ns	ns	ns	ns	ns	ns	4.4	ns	258	ns

Maximum thousand grains weight was recorded (228.44 g) in the plots where N was applied @ 160 kg ha⁻¹, followed by (228.33 g) with 120 kg N ha⁻¹, while the lowest thousand grains weight (222.67 g) was recorded in control plots (N not applied). Organic and inorganic sources of N increase thousand grains weight in maize [12-14]. Among the S levels, thousand grains weight was high (229.17 g) when S was applied at the highest rate of 40 kg S ha⁻¹, while the lowest thousand grains weight (222.58 g) was obtained in the plots where no S was applied (control). Thousand grains weight in maize increased significantly with the application of S compared with control [13, 14].

Grain yield (kg ha⁻¹)

Statistical analysis of the data indicated that N, S levels and their interaction had significant effects on grain yield ha⁻¹ (Table

1). Maximum grain yield (3122 kg ha⁻¹) was obtained in the plots where N was applied @ 160 kg ha⁻¹, while minimum grain yield (2039 kg ha⁻¹) was obtained in the plots where N was not applied. Among the S levels, the highest grain yield (2882 kg ha⁻¹) was obtained in the plots where S was applied @ 40 kg ha⁻¹, and the lowest grain yield (2458 kg ha⁻¹) was recorded in the plot where no S was applied. Grain yield in maize increased @ of 0.99 t ha⁻¹ with application of S up to 40 kg ha⁻¹ [15].

Harvest Index (%)

Statistical analysis of the data indicated that S levels and N levels had significant effects on harvest index, while their interactions had non-significant effect on harvest index (Table 1). Among N levels, harvest index was high (27.8%) in the plots where N was applied @ 160 kg N ha⁻¹, followed by (27.6%) with 80 kg N ha⁻¹, while the lowest harvest index (21.6%) was recorded in

control (N not applied). Application of inorganic sources of N increased harvest index of maize because of more dry matter synthesis through the process of photosynthesis and more assimilation through the activity of active enzymes [1]. Among S levels, harvest index was high (27.7%) when S was applied at the highest rate of 40 kg ha⁻¹, while the harvest index was less (24.5%) in the plot where S was applied at the rate of 20 kg ha⁻¹. Harvest index showed positive relationship with the increase in grain yield and yield components in maize [16].

Conclusion

Based on the grain yield data, all the three levels of N gave higher grain yield than the control (N not applied), and the increase in N levels increased grain yield. Similarly, the two S levels resulted in the higher grain yield than the control (S not applied), and the increase in S levels increased grain yield. The application of 40 kg S ha⁻¹ increased grain yield to maximum 3209 and 3429 kg ha⁻¹ when N was applied at 120 and 160 kg ha⁻¹, respectively.

Recommendations

1. Application of S and N are necessary for increasing maize productivity in the study area.
2. Application of the highest S (40 kg S ha⁻¹) and N levels (160 kg N ha⁻¹) could increase maize productivity in the study area.
3. Further research is needed to find out the best S and N levels for increasing the productivity and profitability of major crops in the study area.

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