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Effect of Applied Nitrogen and Potassium on Source and Sink Development of Maize Growing in Non-Calcic Brown Soils

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ABSTRACT

Maize is the second most important cereal crop grown in Sri Lanka. It needs high amount of nitrogen and potassium for better growth and yield. However, Non-Calcic Brown (NCB) soil is poor in exchangeable potassium. Therefore, a study was conducted to find out the impact of increasing the amount of Nitrogen (N) and Potassium (K)on source and sink development of maize. The experiment was conducted in split plot design where N was used as the main factor (150 and 225 kg/ha) and K (15, 30, 45 and 60 K_2O kg/ha) was the sub factor. Increasing of N increased development of source components where chlorophyll content, above ground bio mass and leaf area; sink of plant where number of grains percob, 100 grain weight and the yield. Potassium significantly affected on sink except number of grains per cob. Interaction of N and K was positively correlated on grains per cob, hundred grain weight and yield from 150 to 225 N kg/ha with all potassium levels. Hence, split application of N (225 kg/ha) with K (60 K_2O kg/ha) would be the optimum level among tested fertilizer combinations for maize growing in NCB soils.

1. Introduction

Non-Calcic Brown soil (NCB, Haplustalf) is one of the coarse textured soils in Sri Lanka with poor nutrient supply [1]. Medium acid soil reaction, poor organic carbon, low availability of P and exchangeable potassium are the important chemical characteristics of the NCB soil [2]. Despite low soil fertility (CEC<10 $cmol_c$/kg) NCB soil is extensively used for crop production [3]. Non-Calcic Brown soils mainly occur in Polonnaruwa and Batticaloa districts in Sri Lanka. The approximate land extent covers under NCB is 163000 ha and this is the one of the dominant great soil groups in the greater part of Mahaweli system B [4]. Maize (*Zea mays* L.) is the second most important cereal crop that can be grown successfully, as a mono crop or component of cropping systems, in many parts of Sri Lanka, under rain fed and irrigated conditions [5]. It has a high demand for nitrogen and potassium and relatively low demand for phosphorous [6]. Literature shows that, nitrogen could mediate the utilization of potassium, phosphorus, and other elements in plants [7]. Nitrogen is an integral part of the chlorophyll and functional proteins, which are important for the development of source and sink of maize [8]. Potassium is also responsible for many physiological and metabolic activities [9]. Before the silking stage of maize, the majority of the K^+ accumulation is completed [8]. Pettigrew, [10] reported that, maize yield is increased by K^+ fertilization. However, Burns and Edelhar [11] observed that K^+ fertilization has no significant effect on maize yield. Approximately 600 ha of uplands are under maize cultivation in Mahaweli system B where NCB soils are dominant [12]. However, no records of the studies could be found about combined effect of both nitrogen and potassium and their interaction on sink and source development of maize in the NCB soils of Sri Lanka. Hence, the objective of this study was to assess the combinational impact of nitrogen and potassium application on the development of source and sink of maize grown in NCB soils.

2. Material and Methods

The field experiment was carried out in the Regional Agricultural Research and Development Centre, *Aralaganwila*, (Latitude 7°46'N and Longitude 81°10'E) in the Low Country Dry Zone. This location comes under the DL_{2b} agro-ecological zone of Sri Lanka. The design of the field trial was a two factor factorial split plot with three replicates. A local variety *Sampath,* which has a potential yield of 9 t/ha under existing management, was used for this study [13]. It has been reported that, variety *Sampath* performed well at the rate of 150 kg/ha of N with standard plant density [14]. In this study variety *Sampath* was tested with two factors: a) 2 level of N (150 and 225N kg/ha) and b) 4 levels of K (15, 30, 45 and 60 K_2O kg/ha). Nitrogen and K levels tested in this study are shown in table 1 as percentages of Department of Agriculture recommendation. The number of splits of fertilizer application is given in table 2. Department of Agriculture (DOA) recommended level of P(45 P_2O_5 kg/ha) was added to all treatments. Land was prepared well by ploughing and leveling, then in 5m×3m size experimental plots were arranged and 3 to 4 seeds per planting holes were placed with 60 cm×60 cm spacing. After germination, the plants were thinned down to two plants per hill. Crop management was done as recommended by the DOA under irrigated conditions leaving minimal room for any biotic and abiotic stresses. The experiment was arranged to facilitate irrigation through input channels and drainage was facilitated by out flow channels to avoid mixing fertilizers between the plots. Fifty-centimeter space was allowed between replicates. Experimental plots were irrigated once a week starting from the emergence of the seedlings until pod filling stage.

Table1. Percentage of nitrogen and potassium application under different treatments

Treatment	*Treatment details*	*Percentage of N and K_2O as per the DOA recommendation in each treatment*	
		N fertilizer	*K_2O fertilizer*
N_1K_1	150N kg/ha+15 K_2O kg/ha	100%	50%
N_1K_2	150N kg/ha+30K_2O kg/ha	100%	100%
N_1K_3	150N kg/ha+45 K_2O kg/ha	100%	150%
N_1K_4	150N kg/ha+60 K_2O kg/ha	100%	200%
N_2K_1	225N kg/ha+15 K_2O kg/ha	150%	50%
N_2K_2	225N kg/ha+30K_2O kg/ha	150%	100%
N_2K_3	225N kg/ha+45 K_2O kg/ha	150%	150%
N_2K_4	225N kg/ha+60 K_2O kg/ha	150%	200%

Table 2. The number of splits and the time of fertilizer applications

Time of application	N level		P_2O_5level	K_2O levels			
	(N_1)	(N_2)		(K_1)	(K_2)	(K_3)	(K_4)
Basal	34. 5	52	45	15	30	30	30
4WAP*	115. 5	173	0	0	0	15	30
Total supply	150	225	45	15	30	45	60

3. Results and Discussion

3.1 Main effect of N and K on sink source development and yield

Main effect of applied N on leaf area, SPAD reading, above ground biomass, number of grains per cob, 100 grain weight and grain yield were significant (Table 3). Level of 225 N kg/ha recorded the highest leaf area, SPAD reading, above ground biomass, number of grains per cob and the grain yield compared to said parameters of 150 N kg/ha. Effect of K was also significant on above parameters except SPAD readings and number of grains per cob (Table 3). Application of higher K_2O rates has significantly increased the leaf area when compared with 15 kg/ha K_2O application across the applied N levels. The highest 100 grain weight (19.9 g) was recorded by 60 kg/ha K_2O while, the lowest value was given by the 15 Kg/ha K_2O (16.9 g).However, highest yield was recorded in the 15 kg/ha K_2O application across all the N levels. Interaction effects of N and K on 100 grain weight, number of grains per cob and grain yield were also significant (Table 3).

Table 3. Main effect of different nitrogen and potassium on growth and yield of maize in NCB soil.

Fertilizer level	*Leaf area (cm^2/plant)*	*SPAD reading*	*Above ground Biomass (g/plant)*	*Number of grains/cob*	*100 grain weight(g)*	*Grain yield (t/ha)*
p value	<0. 0001	<0. 0001	<0. 0001	0. 04	<0. 0001	<0. 0001
N (kg/ha)150	418. 0b	35. 3b	61. 7b	181. 7b	17. 6b	1. 8b
225	945. 1a	49. 7a	75. 2a	255. 7a	20. 8a	2. 65a
p value	0. 03	ns	0. 01	ns	0. 001	0. 008
K_2O (kg/ha)15	607. 2b	46. 0a	65. 3b	263. 9a	16. 9c	2. 73a
30	829. 7a	45. 9a	73. 1ab	235. 4a	18. 2b	2. 2c
45	933. 6a	46. 1a	79. 3a	255. 8a	18. 4b	2. 55ab
60	985. 4a	49. 6a	78. 3a	213. 3a	19. 9a	2. 3bc
p value N*K	0. 05	ns	ns	0. 04	0. 03	<0. 0001
CV%	23. 8	7. 36	12. 6	8. 31	6. 0	12. 7

Within each column, the mean fallowed by the same letters are not significantly different at 0.05 probability level by DMRT

3.2 Interaction effect of growth and yield of maize with different levels of K within fixed N levels.

Interaction effects of N and K on number of grains per cob was positive in all K levels with range of levels from 150 to 225 N Kg/ha (Figure 1). The highest seeds per cob was recorded by the combination of 60 Kg/ha K_2O with 225 N Kg/ha. Interaction effect of applied N and K on 100 grain weight was positive with increasing N from 150 to 225 Kg/ha in all K levels (Figure 2). The highest 100 seeds weight was recorded in 225 N kg/ha combined with 60 K_2O kg/ha.

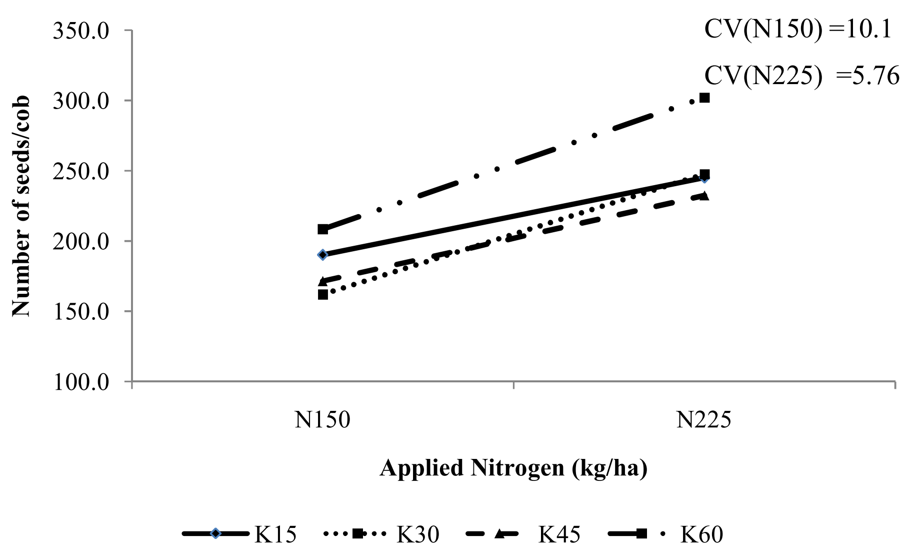

Figure 1. Interaction effect of N and K on number of seeds/cob after keeping N factor fixed

The interaction effect of the N and K on grain yield was also positive in all K levels with increasing N level from 150 to 225 kg/ha (Figure 3). According to the findings, yield was positively correlated with number of seeds per cob (Table 4). A significant positive correlation was also observed in hundred grain weight with SPAD meter reading, leaf area and bio mass content. Leaf area also showed significant positive correlation with above-ground biomass content as well.

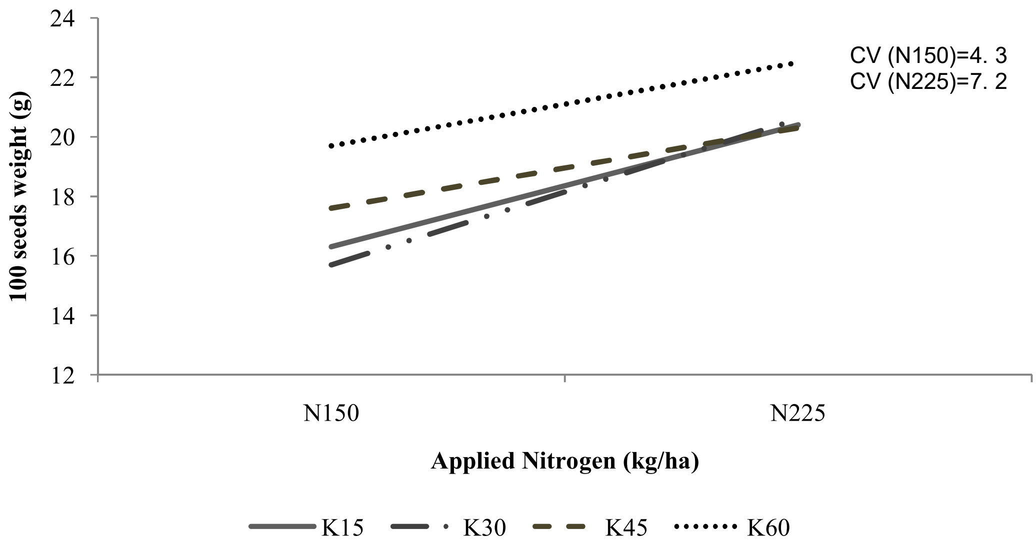

Figure 2. Interaction effect of N and K on 100 seeds weight after keeping N factor fixed

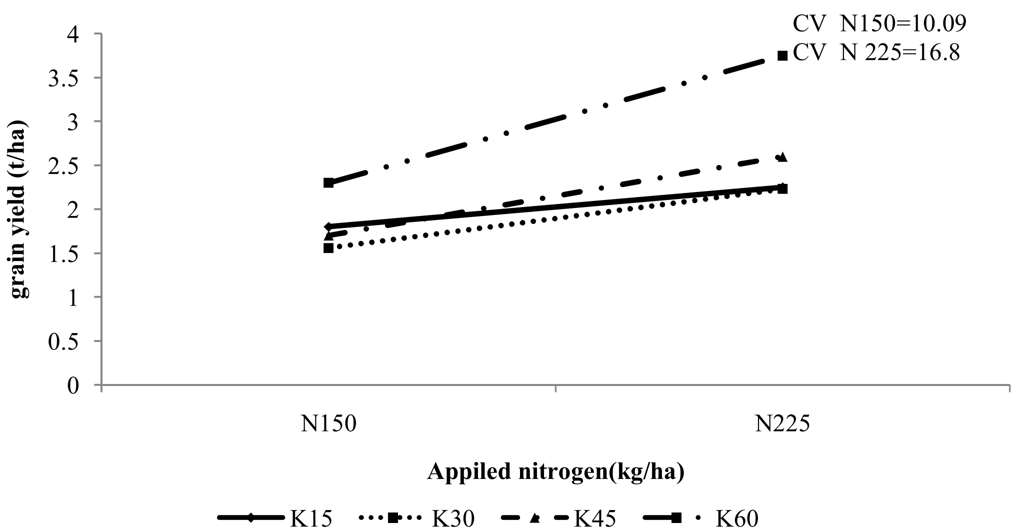

Figure 3. Interaction effect of N and K on grain yield after keeping N factor fixed

Nitrogen is the major component of leaf chlorophyll content, as well as major nutrient that is related to the leaf area development of maize [15]. Thus, the amount of chlorophyll content distributed though out the leaf area can be considered as a source of the plant [16]. Therefore, it can be stated that the application of 225 kg/ha of N significantly increased the source development of maize. Many scientist suggested that, above ground bio mass of maize is highly related to the amount of radiation absorbed by the canopy, when biotic and abiotic stress on the plant does not exist or minimal [17, 18]. Therefore, increasing N could have contributed to the increase in the source fraction of the plant. Hence the plant could utilize more solar radiation and produced more assimilates. Further, increase in the number of seeds in a cob with the increase in nitrogen application facilitate more sink for the accumulation of assimilates in a cob.

Table 4. Pooled correlation between yield (YLD), number of grains per cob (NSC), 100 grain weight (HSWT), SPAD meter reading (SPAD), leaf area (LA), above ground biomass (BM), of different N and K levels on maize grown in NCB soil.

	YLD	*NSC*	*HSWT*	*SPAD*	*LA*	*BM*
YLD		0. 95***	-0. 05ns	0. 08ns	0. 002ns	0. 20ns
NSC			-0. 22ns	-0. 09ns	-0. 17ns	0. 06ns
HSWT				0. 85***	0. 89***	0. 76**
SPAD					0. 95***	0. 83***
LA						0. 86***
BM						

Significant at p=0. 005* Significant at p=0. 0001; ns - Not significant

Potassium is not an integral component of any structural part of the plant in maize [10]. Therefore, the application of more K than the current recommendation may not have increase the source fraction of the plant significantly. However, it has enhanced the sink components. The yield and hundred seed weight were increased by adding 60 kg/ha K_2O. It could be a result of an increase in the translocation efficiency of assimilates from source to sink through phloem loading and enhancing other metabolic activities such as water relation, stomatal function during photosynthesis [10].

Further, interaction results suggested that, the increase in the N level from 150 to 225 kg/ha positively affected on number of grains per cob, hundred grain weight and yield. The increase of N could have produced more assimilates through photosynthesis, although the translocation of assimilates from leaves (source) to seeds (sink) could be less in the lower levels of K. Therefore, efficient translocation of increased assimilates requires more potassium.

Number of seeds per cob was mainly determined by nitrogen [18,19] and the present experiment has confirmed the same. Furthermore, K has synergistic effect on the activity of N in the plant. Hence, it could be said that, when the N application to maize is increased a simultaneous increase in K is preferable to obtain the full benefits of the application. However, in this experiment only two N levels along with four K levels were tested and the best performed combination includes the highest application rates of both nutrients. Therefore, it could be assumed that further increase of application rates could be possible to reach a higher yield level. Therefore, further experiments could be conducted in terms of increasing application rates and the approach of application such as timing of application.

4. Conclusions

It can be concluded that, the main contributing factor for the development of sink and source of maize growing on NCB soil is the amount of applied nitrogen. Potassium could facilitate the sink process by enhancing assimilate translocation through phloem. Split application of N at the rate of 225 kg/ha with K at 60 kg/ha K_2O would be the optimum level among tested fertilizer combinations for maize growing in NCB soils.

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