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EFFECT OF N APPLICATON AND N SPLITING STRATEGY ON MAIZE N UPTAKE, BIOMASS PRODUCTION AND PHYSIO-AGRONOMIC CHARACTERSTICS

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ABSTRACT

Inefficient use of nitrogen fertilizer, proper application method and time are major constraint for low productivity. Management strategies that maximize N utilization through proper application method and timing by minimizing N losses are necessary for enhancement of maize fodder productivity. A field research experiment was conducted to assess the effect of methods (broadcast, fertigation and side dressing) in combination with different N splitting strategies (140 N kg ha^{-1}) The effect of one N application dose dose vs. two split (at planting and V4), three split (at planting, V4, and V6), four split (at planting, V4, V6 and V8) and five split (at planting V4, V6, V8 and V10) on maize variety Akbar grown for biomass production was evaluaed. The treatment of three splits of N fertilizer at a total rate of 140 kg ha^{-1} applied through fertigation at planting, V4 and V6 stages significantly increased number of leaves per plant, plant height, stem girth, biomass production, leaf area index, leaf area duration, crop growth rate, total dry matter, N content and N uptake, However, broadcast and side dressing application methods were ranked at 2nd and 3rd place respectively. It is thus recommended that three split N application of 140 kg ha^{-1} through fertigation at planting, V4 and V6 stages could be efficient for achieving good quality characters and maximum biomass production of maize.

Key Words: **Maize, Fodder, Nitrogen, Agronomy, Physiology, Growth, Uptake**

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INTRODUCTION

The most logical approach to increasing N fertilizer use efficiency is to supply N when it is needed by the crop (Keeney, 1982). Use of optimum amount of fertilizer through a suitable application method at a time when it is most efficiently and effectively utilized is imperative. Placement of fertilizer is an integral part of efficient crop management. It can affect both crop yield and nutrient-use efficiency (Johnston and Flower, 1991). Rafique and Afzal (1982) reported that banding of nitrogen fertilizer was superior to broadcast method. Band application of fertilizer gave higher yield than broadcast (Hussain, 1976; Khattak *et al.* 1988). Fertigation technique can reduce fertilizer application costs by eliminating extra operation and improve nutrient efficiency. Also, it could conceivably reduce leaching or de-nitrification (gaseous) losses of nitrogen and lower the luxury uptake of nutrients by plants. Fertigation enable users to apply the fertilizers in plant root zone or on canopy in desired frequency, amount and concentration at appropriate time (Kumar *et al*., 2000). Significant reduction in nutrient loss could be achieved through fertigation compared to other fertilizer application methods (Hebbar *et al*., 2004). Carefoot *et al*. (1990) reported that difference in yield and N derive from fertilizer were related to mobilization of ammonium nitrate, this depends on the degree of contact between the fertilizer, crop residue and soil moisture levels. Lower recovery of N has been attributed to immobilization of N with surface application of nitrogenous fertilizer (Fredrickson *et al*. 1982). Previous research suggests that because of possibilities of increased immobilization of broadcast N, banding fertilizer N below the surface residue layer may be necessary (Malhi *et al*. 1988). Efficient use in fertilizer requires contact between fertilizer and crop residue and could be minimized by placing N below surface (Rice and Symth, 1994). Half of the recommended dose of fertilizer application through fertigation was equally effective to produce yield that of conventional method of irrigation and fertilizer application (Tumbare, 1999) and 25-50% fertilizer could be saved. Moreover, a saving of 30-15-

15 kg NPK ha^{-1} was recorded through fertigation application against the recommended NPK levels (Balasubramanian *et al.* 1999). Other researchers have reported that fertilizer application either by broad or placement methods did not affect growth and yield components of maize (Faungfupong and Sakhunkhu, 1985; Girardin *et al.* 1992.

Starter fertilization is often applied to increase early plant weight and height (Reeves *et al.* 1986; Touchton, 1988; Mascagni and Boquet, 1996; Gordon *et al.* 1997; Mallarino *et al.* 1999; Vetsch and Randall, 2002). A review by Randall and Hoeft (1988); Hoeft *et al.* (1995); Scharf (1999); Bermudez and Mallarino (2002, 2003) indicate that starter N or P usually explain the crop responses. Low soil N status early in the season could cause delay in maximum rate of N uptake (Russelle *et al.* 1983). Jokela and Randall (1989) attributed high soil residual nitrate as the reason for a lack of N response by maize when applied at the V8 stage. Maize begins to rapidly take up N during the middle of vegetative growth period with the maximum rate of N uptake occurring near silk (Hanway, 1962). Thus, applying N as side dress (V8-V10) should be one of the best ways of supplying N to meet this high demand. This appears to be substantiated in studies where side dressing N results in fertilizer use efficiencies greater than that produced by applying pre plant N (Miller *et al.* 1975; Olson *et al.* 1982; Reeves and Touchton, 1986; Welch *et al.* 1971). Delaying N application too long, however, may reduce yield and N fertilizer recovery (Jung *et al.* 1972). Most of the researchers have been suggesting that N should be applied nearest to the time it is needed by the crop, i.e. side dressed several weeks after maize emergence (Welch *et al.* 1971; Stanley and Rhoads, 1977; Russelle *et al.* 1981; Olson and Kurtz, 1982; Aldrich 1984; Fox *et al.* 1986).

In a study on corn grown on organic soil, it was reported that applying N at V4-6 growth stage had a significant advantage over applying all N at planting. The economic return was also highest for the split treatment (40% pre-plant and 60% side dress at V8 stage) (Randall *et al.* 2003). Side-dressed N on sandy soils is usually more effective than pre-plant N (Bundy, 1986). A 3-yr field experiment on a silt loam showed that side dress N had more efficient N use, particularly with urea-containing sources (Fox *et al.* 1986). In medium and fine textured soils, split application increased yield and nitrogen use efficiency and there was no potential leaching loss difference in the split N application (Randall and Schmitt, 1998). The objectives of this research, therefore, were to determine how N application timings and methods can enhance yield expression, and to understand better interactive effect of N application timing and methods to provide better alternative management practices to the farmers facing problem of low maize fodder yield.

MATERIALS AND METHODS

Field experiment was conducted at Students Farm, Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan, during 2009 (25°25'60'N 68°31' 60E) at altitude 19.5 m above sea level. Soil was clay loam, non-saline (EC 0.98 dS/m), slightly alkaline in reaction pH (7.8) calcareous ($CaCO_3$ 9.7%), low in organic matter (0.7%), total nitrogen content (0.04%) and available phosphorus (3.9 mg P kg^{-1} soil), but high in exchangeable potassium (172 mg K kg^{-1} soil).

Maize variety Akbar grown for fodder production was treated with three nitrogen placement methods (broadcast, side dressing and fertigation) and five N application time viz. control, two Split (at planting and V4), three Split (at planting, V4, and V6), four Split (at planting, V4, V6, V8), and five Split (at planting, V4, V6, V8 and V10) (Backingham, 2007). The experiment was designed as randomized complete block design in factorial arrangement with three replicates on net plot area of 15 m^2.

Land was prepared by deep plowing followed by leveling for equal distribution of irrigation and eradication of weeds. All treatments received one dose of P fertilizer at a rate of 65 kg ha^{-1} in the form of Single Super Phosphate (SSP) applied at the time of sowing; however, N was applied as per treatment. The crop for biomass production was harvested at 50% tasselling.

Broadcast Nitrogen fertilizer was applied as urea on the surface was applied as per treatment. Fertigation Urea as per N treatment was diluted in water (as per calibration) and filled in container having a small hole. The container was kept on the water channel of the plot to pass-out the water-urea concentration. Side Dressing Nitrogen fertilizer was applied along with the side of plants, about 0-3 inches away from the plants.

Measured Parameters

Germination (%): At 85% emergence of seedlings.

Green leaves Plant^{-1}: at harvest, by counting the leaves

Plant Height: at harvest, through measuring tape, from the ground level to the top of flag leaf.

Stem Girth: measured, using measuring tape at three places of each plant (i.e bottom, middle and top of the plants and averages were calculated.

Biomass: By harvesting m^2 and estimates were made for hectare.

Total dry matter: Oven dried at 80 ^{0}C and weighed of biomass production.

Leaf area index (LAI): Leaf area index was calculated by the following formula described by Radford (1967).

$$LAI = LA / GA$$

Leaf Area Duration (LAD): it was determined through the methods described by Hunt. (1978).

$$LAD = (LAI_2 + LAI_1)\ (t_2 - t_1)/2$$

Crop Growth Rate (CGR) (g m^2 day^{-1}): it was worked out through the standard procedures described by Hunt (1978) as under:

$$CGR = (W_2 - W_1) / (t_2 - t_1)$$

Nitrogen content (%): nitrogen content was by Kjedahl method as described by Jackson (1958).

Nitrogen Uptake (kg ha^{-1}): was determined through; TDM x N concentration in plant/(100).

Statistical Analysis

Data were statistically analyzed through MSTATC computer software. The LSD value for mean comparison was calculated only if the general treatment *F* test was significant at a probability of ≤ 0.05 (Gomez and Gomez, 1985).

RESULTS AND DISCUSSION

Effect of Split Nitrogen Application

Split application of nitrogen significantly enhanced all plant traits except emergence. Higher number of leaves per plant (14.8), plant height (163 cm), stem girth (5.7 cm), biomass production(79.53 t ha^{-1}), leaf area index (13.16), leaf area duration (169 days), crop growth rate (16.05 g m^2 day), total dry matter (8.60 t ha^{-1}), N content (1.15%) and N uptake (99.08 kg ha^{-1}) were in three split application of 140 N kg ha^{-1} through fertigation at planting, V4 and V6 stage. However, values of all plant traits decreased when N was applied in two, four or five splits. The higher values found in three N split applications could be due to better utilization of nitrogen at proper time and growth stage (Table I-II). Previous studies, (Diekow *et al*. 1998) shows that split application of fertilizer at different growth stages had significant effect on maize fodder yield. These results are contrary with those of Jones (1973) who indicated that time of application of N had no significant effect on maize plant characters.

Effect of N Placement Methods

In this study nitrogen placement methods also had significant effect on all the crop traits. Significantly more leaves (13.6 $plant^{-1}$), plant height (159 cm), stem girth (5.5 cm), biomass production (75.71 t ha^{-1}), leaf area index (10.78), leaf area duration (152 days), crop growth rate (15.48 g m^2 day), total dry matter (8.29 t ha^{-1}), N content (1.06 %) and N uptake (88.15 kg ha^{-1}) were found in N fertigation compared to rest of N application methods (Table I-II). Earlier researchers (Hussain, 1976; Rafique and Afzal, 1982; Khattak *et al*. 1988) showed that band placement of nitrogen produced significantly higher yield and uptake than broadcast application. However, conventional methods of N application viz. broadcast and side dressing could not prove their efficiency and were ranked at 2nd and 3rd place. More possibly, fertigation had less N losses in the field compared to other N application methods. Some researchers reported that fertilizer application either by broad or placement methods did not affect growth of maize (Faungfupong and Sakhunkhu, 1985; Girardin *et al.,* 1992).

Table I. *Agronomic traits of maize as affected by nitrogen application time and application methods*

Treatments	Germination (%)	Leaves plant^{-1}	Plant height (cm)	Stem girth (cm)	Biomass (t ha^{-1})
N application time					
Control	84	9.7 d	68 d	2.5 e	18.92 e
Planting,V4	85	12.3 c	139 c	4.8 d	61.50 d
Planting,V4,V6	85	14.8 a	163 a	5.7 a	79.53 a
Planting,V4,V6,V8	85	13.0 b	147 b	5.4 b	73.47 b
Planting,V4, V6, V8,V10	85	13.0 b	147 b	5.1 c	70.03 c
SE	0.526	0.128	0.905	0.028	0.832
LSD (5%)	--	0.359	2.535	0.079	2.33
N application methods					
Broadcast	83	12.8 b	147 b	4.6 b	63.20 b
Fertigation	84	13.6 a	159 a	5.5 a	75.71 a
Side dressing	84	11.4 c	93 c	4.1 c	43.21 c
SE	0.407	0.099	0.701	0.025	0.744
LSD (5%)	--	0.278	1.964	0.061	1.806

Means followed by common letter are not significantly different at 5% probability level.

Table II *Physiological and N uptake traits of maize as affected by nitrogen application time and application methods*

Treatments	**LAI**	**LAD (days)**	**CGR (gm^2 day^{-1})**	**TDM (t ha^{-1})**	**N content (%)**	**N uptake (kg ha^{-1})**
N application time						
Control	3.55 e	46 e	13.02 e	6.98 e	0.29	20.18 d
Planting,V4	9.19 d	118 d	15.30 d	8.20 d	0.96	78.83 c
Planting,V4,V6	13.16 a	169 a	16.05 a	8.60 a	1.15	99.08 a
Planting,V4,V6,V8	10.47 b	135 b	15.64 b	8.38 b	1.07	89.75 b
Planting,V4,V6,V8,V10	10.04 c	130 c	15.44 c	8.27 c	0.97	80.58 c
SE	0.105	1.201	0.107	0.018	--	0.784
LSD (5%)	0.295	3.36	0.142	0.051	--	2.198
N application methods						
Broadcast	9.33 b	121 b	15.09 b	8.09 b	0.90	73.00 b
Fertigation	10.78 a	152 a	15.48 a	8.29 a	1.06	88.15 a
Side dressing	6.73 c	86 c	14.70 c	7.88 c	0.76	59.90 c
SE	0.081	0.930	0.029	0.014	--	0.607
LSD (5%)	0.228	2.60	0.083	0.039	--	1.702

Means followed by common letter are not significantly different at 5% probability level.

Combined Effect of Splitting and Application Method

Split application of nitrogen at 140 kg ha^{-1} through different N application methods significantly increased agronomic, physiological and N uptake parameters of maize. Significantly maximum leaves (16.6 plant^{-1}), plant height (200 cm), stem girth (7.0 cm), biomass production(100.5 t ha^{-1}), LAI (17.18), LAD duration (221 days), CGR (16.47 g m^2 day), TDM (8.82 t ha^{-1}), N content (1.36%) and N uptake 120 kg ha^{-1} were recorded with three split applications of 140 kg ha^{-1} through fertigation at planting, V4 and V6 stage. Further N split reduced the values of all crop measures (Table III-IV).

Table III. ***Interactive effect of N application methods and application time on agronomic traits of maize***

Treatments	Germination (%)	Leaves plant^{-1}	Plant height (cm)	Stem girth (cm)	Biomass (t ha^{-1})
N application methods x N application time					
Broadcast					
Control	81	10.0 f	67 i	2.4 i	18.70 i
Planting,V4	84	13.0 d	159 e	4.5 g	65.00 e
Planting,V4,V6	85	15.0 b	180 b	5.5 d	82.00 c
Planting,V4,V6,V8	84	13.0 d	165 d	5.3 e	77.00 d
Planting,V4,V6,V8,V10	85	13.0 d	165 d	5.1 e	73.20 d
Fertigation					
Control	85	9.3 g	69 i	2.4 i	18.83 i
Planting,V4	85	14.0 c	172 c	5.7 d	75.00 d
Planting,V4,V6	85	16.6 a	200 a	7.0 a	100.50 a
Planting,V4,V6,V8	84	14.0 c	177 b	6.4 b	93.20 b
Planting,V4,V6,V8,V10	84	14.0 c	177 b	6.1 c	91.00 b
Side dressing					
Control	85	10.0 f	68 i	2.5 i	19.33 i
Planting,V4	85	10.0 f	87 h	4.2 h	44.50 h
Planting,V4,V6	84	13.0 d	111 f	4.8 f	56.25 f
Planting,V4,V6,V8	85	12.0 e	100 g	4.9 g	50.00 g
Planting,V4,V6,V8,V10	85	12.0 e	100 g	4.2 h	46.00 gh
SE	0.911	0.222	1.568	0.048	1.442
LSD (5%)		0.622	4.391	0.182	4.039

Means followed by common letter are not significantly different at 5% probability level.

Table IV ***Interactive effect of N application methods and application time on physiological and N uptake traits of maize***

Treatments	LAI	LAD (days)	CGR (gm^{2}day^{-1})	TDM (t ha^{-1})	N content (%)	N uptake (kg ha^{-1})
N application methods x N application time						
Broadcast						
Control	3.65 i	47 h	12.94 i	6.95 j	0.28	19.76 j
Planting,V4	9.27 f	119 e	15.49 de	8.30 ef	0.97	80.50 f
Planting,V4,V6	13.44 b	173 b	16.05 b	8.60 bc	1.11	95.75 d
Planting,V4,V6,V8	10.42 d	134 d	15.59 de	8.35 e	1.07	89.25 e
Planting,V4,V6,V8,10	9.88 e	130 d	15.40 ef	8.25 fg	0.97	79.75 f
Fertigation						
Control	3.39 i	45 h	13.11 i	7.02 j	0.30	20.78 j
Planting,V4	12.26 c	158 c	15.82 c	8.47 d	1.06	90.00 e
Planting,V4,V6	17.18 a	221 a	16.47 a	8.82 a	1.36	120.00 a
Planting,V4,V6,V8	13.40 b	172 b	16.10 b	8.62 b	1.28	110.00 b
Planting,V4,V6,V8,V10	12.68 c	163 c	15.91 bc	8.52 cd	1.17	100.00 c
Side dressing						
Control	3.62 i	46 h	13.02 i	6.97 j	0.29	20.00 j
Planting,V4	6.03 h	77 g	14.61 h	7.82 i	0.84	66.00 h
Planting,V4,V6	8.87 f	114 e	15.63 d	8.37 e	0.97	81.50 f
Planting,V4,V6,V8	7.59 g	97 f	15.26 f	8.17 g	0.86	70.00 g
Planting,V4,V6,V8,V10	7.55 g	97 f	15.03 g	8.05 g	0.77	62.00 i
SE	0.182	2.08	0.066	0.031	-	3.359
LSD (5%)	0.511	5.82	0.186	0.088	-	5.033

Means followed by common letter are not significantly different at 5% probability level.

In this study, time of N application was a significant factor as shown by all the measured plant parameters. Values of all the traits decreased significantly when two, three and five N splits were made (planting and V4), (planting, V4 and V6) and (planting, V4, V6, V8 and V10) respectively. However, four N splits (planting, V4, V6 and V8) was a superior treatment, giving maximum values of all crop traits. In some studies timing of fertilizer N had variation (Russelle *et al*. 1981; Randall *et al*. 1988). However, Gerwing *et al.* (1998) found split pre-plant and sidedress application improved plant N uptake. Late or early application of N probably does not allow sufficient time for activities of physiological, agronomic and N uptake traits. Binder *et al.* (2000)

also found that maize yields declined when N applications were delayed. It is reported that fertilizer N recovery by crop may sometimes be greater when N application is delayed compared with application at planting (Russelle *et al*., 1983; Jokela and Randall, 1997). This is probably due to greater exposure of N applied at planting to a range of possible loss processes (immobilization, leaching, denitrification, and clay fixation) at a time when N uptake rates are relatively low. Rate of N uptake as the maize plant develops is affected by weather, planting date, and time of fertilizer application but is generally greatest between V8 and silk stage (Russelle *et al*. 1983).

In this study, split application of 140 kg ha^{-1} through traditional method of broadcast or side dress recorded lower values of all agronomic, physiological and N uptake traits compared to fertigation method. Lower recovery of N has been attributed to immobilization of N with surface application of nitrogenous fertilizer (Fredrickson *et al.,* 1982). Previous research suggests that because of possibilities of increased immobilization of broadcast N, banding fertilizer N below the surface residue layer may be necessary (Malhi *et al.,* 1988). Efficient use in fertilizer requires contact between fertilizer and crop residue and could be minimized by placing N below the surface (Rice and Symth, 1994). Thus, 50% of recommended dose of fertilizer application through fertigation was equally effective to produce yield that of conventional method of and fertilizer application (Tumbare, 1999) and 25-50% fertilizer could be saved (Balasubramanian *et al*., 1999).

Previous reports of Gandahi and Oad (2005) shows that N fertigation application was efficient N application method than broadcast method, because fertigation enable users to put the fertilizers in plant root zone in desired frequency, amount and concentration at appropriate time (Kumar, 2000). Cadahia (1993) also reported the advantages of fertigation and showed as a slow-release fertilizer and lower loss of N due to leaching and therefore a lower degree of ground water contamination which not only increased the N uptake by the plant as well as the leaf and root weight, but it also produces higher yields. This technique also reduces fertilizer application levels and improves nutrient efficiency. The reduce loss of nutrients could be through fertigation compared to soil application of fertilizer (Hebbar *et al.* 2004). Some of these advantages of N application through fertigation are well described in literature (Gascho *et al.* 1984; Threadgill, 1985; Criado, 1996; Hagin and Lowengart, 1996) which include timely nitrogen application, provides excellent uniformity of nitrogen application, may reduce environmental contamination, movement of applied N into the rooting zone by irrigation water and a reduction of soil compaction and mechanical damage to the crop as compared to side-dressing. Fertigation had a consistent effect on total NUE (Hou *et al.* 2007) and a more uniform initial NO_3-N distribution through fertigation (Jiusheng *et al.* 2005).

CONCLUSION AND RECOMMENDATIONS

It is concluded that nitrogen fertilizer enhances growth, yield and N uptake traits of maize grown for biomass. Three splits of N at a total rate of 140 N kg ha^{-1} applied through fertigation at planting, V4 and V6 stages was superior strategy for vertical enhancement of maize biomass compared to broadcast or side dressed N application methods.

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