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Yield Response of Local Long Maturing Sorghum Varieties to Timing of Nitrogen Fertilizer Application in Eastern Amhara Region, Ethiopia

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Abstract
Split-application of nitrogen fertilizer experiment was conducted in major late maturing local sorghum varieties growing areas of Eastern Amhara Region namely Sirinka and Kobo for one year (2013). The principal objective of the experiment was to identify the response of timing of nitrogen fertilizer application on grain yield of sorghum. The experiment was designed in randomized complete block consisting of five nitrogen fertilizer (69 kg/ha) application times: (1) full-dose at knee height stage, (2) 1/2 at planting + 1/2 at knee height stage, (3) 1/3 at planting + 2/3 at knee height stage, (4) 1/3 at planting + 1/3 at knee height stage + 1/3 at stem elongation and (5) 1/2 at knee height + 1/2 at stem elongation stage for late maturing local sorghum varieties (*Degalit* and *Jamiyu*) replicated three times were used in the study. Basal application of 46 kg/ha P_2O_5 fertilizer was made at sowing. The result revealed that split-application of nitrogen had significance difference between yield components of sorghum. From this study, the highest grain yield (6830 kg/ha) was recorded with application time of nitrogen fertilizer full-dose at knee height stage of *Degalit* sorghum at Sirinka. Similarly, the highest grain yield (6540 kg/ha) was recorded with application time of nitrogen fertilizer 1/2 at knee height + 1/2 at stem elongation stage of *Jamiyu* sorghum at Kobo. Mean combined over locations were showed also these facts. It was recommended that the best use of nitrogen fertilizer would be obtained when full-dose of the total requirement is applied at knee height stage for *Degalit* sorghum while 1/2 at knee height + 1/2 at stem elongation was for *Jamiyu* sorghum.
Key words: application time, nitrogen fertilizer, growth stages of sorghum

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the most important cereal crop in Ethiopia ranking third in area coverage after tef and maize. In Amhara region, sorghum covered a significant amount of cultivated land following tef. Kobo is one of the potential areas of North Wello zone where sorghum is largely produced. Sorghum contributes the highest share (43.74 %) of production as compared to other crops grown in the zone (Ermias *et al.*, 2007). Sorghum is adapted to a wide range of ecological conditions primarily in hot and warm areas. It withstands extreme heat better than other crops. It can tolerate hot and dry conditions but can also be grown in areas of high rainfall.

Sorghum grain plays the first role in the daily diet of the people used as food and local beverages. The stalk is used for animal feed, construction and even as a cash source by selling it for fuel in towns. Despite its importance, sorghum productivity and production remained very low owing to different biotic and abiotic production constraints. Moisture stress, low soil fertility, poor crop management practices for instance timing of nitrogen fertilizer application and sorghum pests are the major sorghum production constraints (Gebreyesus Brhane, 2012). Erratic and unreliable rainfall is the most serious physical constraint for sorghum production in dry land areas as compared to timing of nitrogen fertilizer application. Under these conditions there is a considerable risk of crop failure, inconsistent stands and high replanting costs. Moisture deficit stress is the key factor that limits crop production in dry land areas (Tewodros Mesfin *et al.*, 2009). Besides to this, timing of nitrogen fertilizer application at the right time and adequate moisture would give significant grain yield of sorghum.

Increase of crop production requires the applications of better technologies. Fertilizer application is a lead practice in the introduction of improved technologies (IFDC, 2002). Increased productivity of sorghum can be achieved by adopting improved agronomic practices and cultivars. Therefore, this research was designed to assess timing of nitrogen fertilizer application on grain yield of sorghum and to assess the advantages of split-application of nitrogen fertilizer at different growth stages of local sorghum varieties.

2. Materials and methods

2.1 Study Area

The experiment was carried out in two localities namely Sirinka and Kobo stations of Eastern Amhara Region, Ethiopia during the main cropping season (April–November) for one year (2013). The altitudes of the experimental areas are 1850 and 1400 m a.s.l. for Sirinka and Kobo, respectively. The mean total annual rainfall (which mainly falls in the cropping season) is 945 mm at Sirinka and 649 mm at Kobo (Figure 1). The rainfall pattern of the areas is bimodal and its distribution is erratic; the effective rainy period extends from June to September. Mean annual average temperatures are 19.5 and 22°C at Sirinka and Kobo, respectively. Soil samples (0–30 cm depth) were taken from the experimental sites before planting. Pre-planting values for pH, total OM, total N, available P, and CEC were 6.59, 1.55%, 0.129%, 12.5 mg kg^{-1}, and 23.44 cmolc kg^{-1}, respectively, at Sirinka, and 6.46, 2.10%, 0.141%, 8.5mg kg^{-1}, and 24.24 cmolc kg^{-1}, respectively, at Kobo.

2.2 Experimental Treatments, Design and Procedures

The experiment was conducted on two sites of sorghum growing areas at Sirinka and Kobo for late maturing local sorghum varieties on-station in the year 2013. Row planting of sorghum 75 cm between rows and 25 cm between plants for late maturing local sorghum varieties were used. The experiment was designed in randomized complete block consisting of five nitrogen fertilizer (69 kg/ha) application times: (1) full-dose at knee height stage, (2) 1/2 at planting + 1/2 at knee height stage, (3) 1/3 at planting + 2/3 at knee height stage, (4) 1/3 at planting + 1/3 at knee height stage + 1/3 at stem elongation and (5) 1/2 at knee height stage + 1/2 at stem elongation replicated three times were used in the study. Plot size of the experiment was 4m x 3m and net harvested rows were two rows from the total four rows of the plot. All agronomic data were taken from the two central rows. Spacing between replications and between plots were 2m and 1m, respectively. Basal application of 46 kg/ha P_2O_5 fertilizer was made at sowing for each plot. Proper agronomic practices were applied as recommended. The late maturing local sorghum varieties *Degalit* and *Jamiyu* were used as planting materials for this experiment. Plant height at maturity (cm), head weight(g), biomass yield, thousand seeds weight and grain yield were collected as growth and yield parameters of sorghum.

2.3 Data Analyses

Data of many important growth and yield parameters collected during the experimental periods were purified and arranged for further analysis. The analysis of variance (ANOVA) was carried out for growth and yield parameters of the study following statistical procedures appropriate for the experimental design using Statistical Analysis System (SAS) program package version 9.0. Whenever treatment effects were significant at 0.01 or 0.05 level of error, the means were separated by using the least significant difference (LSD) test procedures at 0.05 probability level of significance.

3. Results and Discussions

The results of late maturing local sorghum (*Degalit* and *Jamiyu)* varieties of timing of nitrogen fertilizer application at Sirinka and Kobo were showed in the year 2013 (Tables 1-6). *Degalit* sorghum showed highly significant ($p<0.01$) difference between grain yield and significant ($p<0.05$) difference between biomass yield at Sirinka for the year 2013 (Table 1). The highest grain yield (6830 kg/ha) was recorded with application time of nitrogen fertilizer full-dose at knee height stage of *Degalit* sorghum at Sirinka (Table 1). Even if the grain yield was not showed statistically significant, the highest grain yield (6124 kg/ha) was recorded with application time of nitrogen fertilizer 1/2 at knee height + 1/2 at stem elongation stage of *Degalit* sorghum at Kobo (Table 2). On the other hand, *Jamiyu* sorghum showed highly significant difference between grain yield at Kobo for the year 2013 (Table 4). The highest grain yield (6540 kg/ha) was recorded with application time of nitrogen fertilizer 1/2 at knee height + 1/2 at stem elongation stage of *Jamiyu* sorghum at Kobo (Table 4). Even if the grain yield was not showed statistically significant, the highest grain yield (6124 kg/ha) was recorded with application time of nitrogen fertilizer 1/2 at knee height + 1/2 at stem elongation stage of *Jamiyu* sorghum at Sirinka (Table 3).

Mean combined analysis over locations of timing of nitrogen fertilizer application were showed highly significant differences between plant height, biomass yield and thousand seeds weight in case of locations at *Degalit* sorghum (Table 5). Similarly, highly significant difference was observed between plant height and significant difference between thousand seeds weight in case of locations and significant difference between grain yield of *Jamiyu* sorghum for the year 2013 (Table 6). The highest grain yield (6332 kg/ha) was recorded with application time of nitrogen fertilizer 1/2 at knee height + 1/2 at stem elongation stage of Jamiyu sorghum (Table 6). Even if the grain yield was not showed statistically significant, the highest grain yield (5846 kg/ha) was recorded with application time of nitrogen fertilizer full-dose at knee height stage of *Degalit* sorghum (Table 5).

Split N application at planting, knee height and at stem elongation stages of late maturing local sorghum varieties had increased plant height, head weight, biomass yield and grain yield. According to Ranjith *et al*. (2007), the best yields are obtained when nitrogen application is split for rice. Treatments treated with nitrogen fertilizer at two equal splits (1/2 dose at sowing + 1/2 at tillering) produced high grain and straw yields with the best economic benefit or profitability in teff production as compared to applying full dose at sowing time (Abraha Arefaine, 2013). Nitrogen is the most nutrient required for high grain sorghum productivity (Amal *et al*., 2007). It was recommended that the best use of nitrogen fertilizer would be obtained when full-dose of the total requirement is applied at knee height stage for *Degalit* sorghum while 1/2 at knee height + 1/2 at stem elongation was for *Jamiyu* sorghum. Local sorghum varieties were sown in most cases by farmers was that high yielder and attracted during consumption by the consumers, but the main bottle neck was lack of early rain fall distribution especially at planting time in the months of April to May. It is therefore justifiable to conclude that there should be location specific nitrogen fertilizer application timing. Nitrogen is closely linked to control the vegetative growth of plant and hence determine the fate of reproductive cycle.

According to Tewodros Mesfin *et al*. (2009), profitable crop response to applied nutrients depends on soil water availability. Melaj *et al*. (2003), observed greater yield components when N was applied at tillering compared to sowing in case of bread wheat. Ayoub *et al*. (1994), stated that split N had a little effect on yield, but decreased lodging, while grain weight increased. Time of nitrogen application had significant effect on sorghum yield attributes as reported by (Yohanna, 2014). Generally, split-application of N resulted in superior yield increasing attributes than when the entire N was applied at once (Tilahun Tadesse *et al*., 2013).

4. Conclusions and Recommendations

Nitrogen by nature is volatile or easily leachable by water/heat so that split-application and proper timing of nitrogen application for local sorghum varieties were a vital role in sorghum growing areas. For local sorghum varieties (*Degalit* and *Jamiyu*) it was found that nitrogen fertilizer should be applied full-dose at knee height stage for *Degalit* and 1/2 at knee height and the remaining 1/2 at stem elongation stage for *Jamiyu*. The present nitrogen fertilizer split-application recommendation could be used for local sorghum varieties (*Degalit* and *Jamiyu*) growing areas which have similar amount of recommended fertilizer vis-à-vis soil and climatic condition with that of Sirinka and Kobo. As a future research gap it is better to verify this research finding at the other major local sorghum varieties growing areas of the region so as to derive a dependable nitrogen fertilizer application recommendation.

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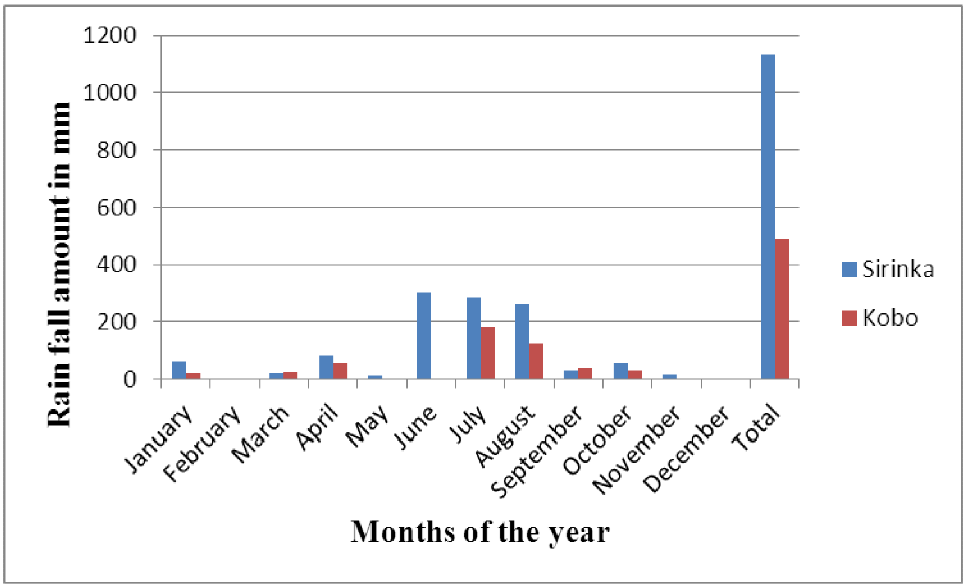

Data from the weather station of the Sirinka and Kobo in 2013
Figure 1. Monthly rain fall distribution at Sirinka and Kobo in the year 2013

Table 1. Mean agronomic traits of yield response of sorghum (*Degalit*) to timing of nitrogen fertilizer application at Sirinka in 2013

Treatments	Head weight/plot (g)	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	5000	349	42222a	43.5	6830a
1/2 AP +1/2 AK	3667	347.7	39556ab	44.1	4605b
1/3 AP + 2/3 AK	3733	344.7	40111ab	44	4854b
1/3 AP + 1/3 AK + 1/3 SE	3200	345	34778c	40.7	4150b
1/2 AK + 1/2 SE	4267	339.7	36444bc	43.1	4083b
LSD (5%)	ns	ns	*	ns	**
CV (%)	20.2	5.3	5.7	8.1	10.6

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. * = significant at $P < 0.05$; ** = Significant at $P < 0.01$; ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

Table 2. Mean agronomic traits of yield response of sorghum (*Degalit*) to timing of nitrogen fertilizer application at Kobo in 2013

Treatments	Head weight/plot (g)	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	3867	237.7	26667	43.1	3990
1/2 AP +1/2 AK	3867	236.7	31222	43.2	4649
1/3 AP + 2/3 AK	4200	242.3	32333	43.9	5282
1/3 AP + 1/3 AK + 1/3 SE	4200	236.3	34333	43	5559
1/2 AK + 1/2 SE	4933	241.3	34611	43.8	6124
LSD (5%)	ns	ns	ns	ns	ns
CV (%)	21.6	4.1	15.9	2.4	18.4

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

Table 3. Mean agronomic traits of yield response of sorghum (*Jamiyu*) to timing of nitrogen fertilizer application at Sirinka in 2013

Treatments	Head weight/plot (g)	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	5200	253	42778	36.9	6084ab
1/2 AP +1/2 AK	5000	252.7	32778	43.3	5508ab
1/3 AP + 2/3 AK	3867	254.3	33333	38	4272c
1/3 AP + 1/3 AK + 1/3 SE	4933	252	33889	41.3	5259bc
1/2 AK + 1/2 SE	5667	249.3	36667	35.6	6540a
LSD (5%)	ns	ns	ns	ns	**
CV (%)	15.2	4.1	17.9	18.2	9.7

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. ** = significant at $P < 0.01$; ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

Table 4. Mean agronomic traits of yield response of sorghum (*Jamiyu*) to timing of nitrogen fertilizer application at Kobo in 2013

Treatments	Head weight/plot (g)	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	3333	289	36123	34.9	4862
1/2 AP +1/2 AK	4200	311.3	24444	38.6	5680
1/3 AP + 2/3 AK	3667	312.7	25556	33.5	4699
1/3 AP + 1/3 AK + 1/3 SE	4667	323.3	18893	39.5	5021
1/2 AK + 1/2 SE	3400	307.3	29444	33	4361
LSD (5%)	ns	ns	ns	ns	ns
CV (%)	24.2	5.9	31.2	14.5	21.6

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

Table 5. Mean combined over locations (Sirinka and Kobo) agronomic traits of yield response of sorghum (*Degalit)* to timing of nitrogen fertilizer application in 2013

Treatments	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	319	39173	39.2	5846
1/2 AP +1/2 AK	329.5	32000	41.4	5142
1/3 AP + 2/3 AK	328.7	32833	38.7	4777
1/3 AP + 1/3 AK + 1/3 SE	334.2	26835	40.1	4586
1/2 AK + 1/2 SE	323.5	32944	38	4222
LSD (5%)	ns	ns	ns	ns
Locations x Treatments	**	**	**	ns
CV (%)	5.9	19.7	11.7	18

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. ** = Significant at $P < 0.01$; ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

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Table 6. Mean combined over locations (Sirinka and Kobo) agronomic traits of yield response of sorghum (*Jamiyu*) to timing of nitrogen fertilizer application in 2013

Treatments	Plant height (cm)	Biomass yield (kg/ha)	Thousand seeds weight (g)	Adjusted grain yield (kg/ha)
Full-dose AK	245.3	34722	40	4970b
1/2 AP +1/2 AK	244.7	32000	43.2	5078b
1/3 AP + 2/3 AK	248.3	32833	40.9	4777b
1/3 AP + 1/3 AK + 1/3 SE	244.2	34111	42.1	5409b
1/2 AK + 1/2 SE	245.3	35639	39.7	6332a
LSD (5%)	ns	ns	ns	*
Locations x Treatments	**	ns	*	ns
CV (%)	4.5	13.6	13.4	13.6

Means within a column followed by the same letter(s) are not significantly different at $P = 0.05$. *= Significant at $P< 0.05$; ** = Significant at $P< 0.01$; ns = non-significant; AK = at knee height; AP = at planting; ATH = after thinning; SE = at stem elongation

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