Effect of rate and timing of Nitrogen Fertilizer on Sorghum Grain Yield and Yield Related Components

Reducing Land Degradation and Farmers' Vulnerability to Climate Change in the Highland Dry Areas of North-Western Ethiopia

TECHNICAL REPORT OF EXPERIMENTAL ACTIVITIES

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Implemented by

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About the Project

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Cover photo: Field performance of Nitrogen split application for sorghum experiment II | September 2014 | Picture by Nigus Demelash

About ICARDA

The International Center for Agricultural Research in the Dry Areas (ICARDA) is the global agricultural research Center working with countries in the world's dry and marginal areas, supporting them for sustainable agriculture development to help increase their productivity, raise incomes for smallholder farmer families, improve rural nutrition and strengthen national food security. With partners in more than 40 countries, ICARDA produces science based-solutions that include new crop varieties (barley, wheat, durum wheat, lentil, faba bean, kabuli chickpea, pasture and forage legumes); improved practices for farming and natural resources management; and socio-economic and policy options to enable and empower countries to improve their food security. ICARDA works closely with national agricultural research programs and other partners worldwide in Central Asia, South Asia, West Asia, North Africa, and Sub-Saharan Africa.

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Synthesis

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Summary Report

In the framework of the project 'Reducing land degradation and farmers' vulnerability to climate change in the highland dry areas of north-western Ethiopia', the effect of timing and rate of nitrogen (N) fertiliser on the yield and yield components of sorghum was studied at Gumara-Maksegnit watershed, Gondar Zuria woreda, Amhara Region, Ethiopia, with a budget support of ICARDA. In the study area the amount of annual rainfall ranges from 995 to 1175 mm, however; more than 70% of the rain falls within three months (from June to August). In the study area sorghum is growing from long time and it gains much attention by the local people since it has different advantages like for food, for drink and the stovers for animal feed. However, the farmers have failed to give appropriate management for sorghum including input supply. As a result, farmers obtained low yield of sorghum not more than 1 ton/ha. Therefore, the experiment was done to improve yield of sorghum by determining rate and application time of N fertilizer. The experiment was evaluated by the local people and experts during different farmers' field days prepared by GARC, and farmers were encouraged and promised to give appropriate agronomic practices for their sorghum field. The experiment was laid out in randomized block design (RCBD) and investigated in the main cropping season of the year 2013 and 2014 at farmer's field. There were three rates and three application time of N fertilizer and a control (without N fertilizer application), N rates are 41, 64 and 87 kg/ha and with application time of full application at, half at planting, have at knee height, and full application at knee height. The 46 kg/ha P2O5 fertilizer was applied to each plot at planting. All the necessary agronomic practices such as weeding, pest control, row plating, tinning were applied equally for each plot. Data were analysed for variance and LSD at 5% level of significance.

The result revealed that N fertilizer application and timing had significant improved sorghum yield from 1t to 3.7 t per ha. This maximum yield was obtained at application of 87 kg/ha N in two splits. Therefore, it is concluded that split application of N fertilizer is necessary to improve sorghum yield in the Gumara-Maksegnit watershed. Further research should be done on the dissemination of the technologies to farmers

Schematic summary of information

Location:	Abakaliyo Village, Gumara- Maksegnit watershed, Gondar
Easting:	03462230
Northing:	13732003
Elevation:	1994m a.s.l.
Period of implementation:	June, 2013 to December, 2014
Duration of trials:	2 years; 2 seasons
Activity leader(s):	Nigus Demelash; Ertiban Wondifraw, Muuz Gebretsadik
Other researchers:	Meron Lakew, Sisay Ambachew
Technical staff involved:	Melkamu Adane, Tamrat W.

1 Background and rationale

Nitrogen, phosphorous and potassium are the essential elements required for plant growth in relatively large amounts. However, deficiencies of nitrogen and phosphorus are common. Soil nutrients become depleted due to leaching of nitrogen, fixation of phosphorous, soil erosion, and removal by crops (Oldeman et al., 1991; Jarvis, 1996; Zobeck et al., 2000, Holmgren & Scheffer, 2001). To maintain high crop production level, the nutrient status of the soil has to be maintained through crop rotation, addition of manures or application of inorganic fertilizers (WRI, 1997; Weltz et al., 1998). Inorganic fertilizers are important inputs in any agricultural production system because they supply the required nutrients in a readily available form for immediate plant use. Nutrient use efficiency depends on the nature of the nutritive compound, the soil type and the crop demand.

Similarly, the efficiency of the N applied in satisfying the N demand of the crop depends on the type of fertilizer, timing of fertilizer application and seasonal trends (Borghi, 2000; Blankenau et al., 2002). Crop response to N fertilizer is also influenced by soil type, crop sequence and the supply of residual and mineralized N. Therefore, numerous strategies such as use of N sources, slow release fertilizer, placement techniques and nitrification inhibitors have been devised to reduce nitrogen losses and improve fertilizer use efficiency (Slanger and Kerkhoff, 1984; Freney et al., 1992).

Sorghum (sorghum vulgare) is the fourth most important world cereal after wheat, rice and maize. It is a staple food in the drier parts of tropical Africa, India and China (Pursgrove, 1995). It is a major food crop in Ethiopia with approximately 297,000 ha production area per annum (Wortmann et al., 2006). Sorghum is one of the leading traditional food crops in Ethiopia comprising 15-20% of the total cereal production in the country. It is the second major cereal crop next to teff (Eragrostis tef) in consumption and cultivable area (CSA, 2000).

Sorghum (sorghum bicolor (L) Moench) responds to applied fertilizers and can increase yield by over 50%. Recorded yields ranging between 20 kg to 40 kg of grain per kg of applied nitrogen have been reported by House (1983, 1995). Farmers seldom apply fertilizers to sorghum. This is partly because sorghum is often grown under marginal conditions, resulting in relatively low yields and partly due to the fact that fertilizer prices are unfavourably high in relation to sorghum grain price. Further, low usage of fertilizer is therefore due to the fact that yields are usually not high enough to be seriously limited by nutrient supply.

The average yield per unit area of sorghum in Ethiopia is not more than 1.0 t ha-1 (CSA, 2000), which is below the world average of 2.3 t ha-1 (Benti, 1993). Though sorghum yield is constrained by different factors, presence of large areas of low fertile and crust prone soils is the main factor (Morin, 1993; Breman et al., 2001). Wartmann et al (2009) reported that N deficiency is among the top constraints that affect sorghum production in East Africa including Ethiopia. Another research in the central Ethiopia also revealed that yield of sorghum was improved by 26% with pre-plant application of N plus P fertilizers (Abebe et al, 2009). Masebo and Melamo (2016) found that application of 92 and 69 kg ha-1 N and P2O5 fertilizers respectively gave a maximum sorghum yield and yield components. Therefore, it is clear that sorghum production can be improved through application of N and P fertilizers with keeping a good management, but the amount of fertilizer application differs from area to area. Therefore, it is important to evaluate the amount and timing of N fertilizer application on the yield and yield components of sorghum in Gumara Maksegnit Woreda.

2 Objective

The main objective of this research activity was to determine the optimum rates and time of N fertilizer application for maximum yield of sorghum in Gumara-Maksegnit watershed.

3 Experimental Methods

The study was carried out in Gumara-Maksegnit watershed in North Gondar administrative zone in the Amhara National Regional State, Ethiopia. The watershed is located between 120 23' 53" to 120 30' 49" latitude and 370 33' 39" to 370 37' 14" longitude and an altitude. The long term average annual rainfall is about 1052 mm. The mean minimum and maximum temperatures of the area are 13.3 °C and 28.5 °C (NMSA, 2009).

An on-farm experiment was conducted on sorghum on a Vertisols in 2013 and 2014 cropping season. Local Sorghum variety was used and sown at the onset of rains (usually the second week of June). Triple Super Phosphate (TSP), DAP and Urea fertilizers were used as fertilizer source to supply phosphorous (P) and nitrogen. Gross plot size was 3 m x 4.5 m (13.5 m2). Sorghum seeds were sown in rows at spacing of 75 cm between rows and 20 cm within rows and were thinly covered with soil. Plots were kept weed free by hand weeding. 46 Kg/ha P2O5 and all other agronomic practices were applied to each plot equally. Composite soil samples were collected before planting. Soil chemical analysis was done at Gondar Soil Laboratory and the result is as shown in table one:

Table 1: Soil chemical analysis of the study site.

Soil depth/ cm	Surface layer (0-25 cm)								
	OM %	BD g/cm^3	pH H2O 1/2.5	T.N Kjeldhal %	Exch. P Olsen PPm	Sand	Texture Silt	Clay	Texture class
>100	1.54	1.63	7.05	0.10	31.38	30.56	11.68	57.76	Clay

Treatments

10 treatments were applied, summarized in table 2. In the watershed farmers usually plant sorghum at flat land in broad cast. Fertilizers application and other agronomic practices like weeding, row planting and tie-ridging are rarely used. Farmers have their common practice for sorghum planting which is called 'shilshalo' a practice that farmers plow their sorghum plot after well establishment of the plant using oxen for the purpose of tinning and reducing weeds. Some-times they do also remove large weeds after 3 to 4months of planting using sickle and they use the removed weeds for animal feed.

Table 2: Overview of the different treatments

Trt code	N rate kg/ha	N split/timing	Treatment descriptions
1	0		Control = no N fertilizer application
2		N1	41 kg/ha N was applied at planting
3	41	N1/2+1/2	20.5 kg/ha N was applied at planting and the rest 20.5kg/ha was applied at knee height
4		N0+1	41kg/ha N was applied at knee height
5		N1	64 kg/ha N was applied at planting
6	64	N1/2+1/2	32 kg/ha N was applied at planting and the rest 32 kg/ha was applied at knee height
7		N0+1	64 kg/ha N was applied at knee height
8		N1	87kg/ha N was applied at planting
9	87	N1/2+1/2	43.5 kg/ha N was applied at planting and the rest 43.5 kg/ha was applied at knee height
1o		N0+1	87 kg/ha N was applied at knee height

4 Statistical aspects

- Null hypothesis: rate and timing of N fertilize application do not affect yield and yield components of sorghum.
- Statistical design: the design was randomized complete block design with three replications.
- Statistical analysis: whenever significant differences between treatments are detected, mean separation was done using least significant difference (LSD). SAS version 9 statistical software was used for analysis.

The response variables measured were: plant height in cm, head weight in g, Stover yield in ton, head length in cm and yield in ton, each variables was taken from the middle four rows (3 m x3m plot size), 2 rows were left to avoid border effects.

5 Results

The results in the table below showed that there was statistically significant difference ($p < 0.05$) in number of tillers per plant, grain yield and stover yield between treatments. Maximum grain yield (3.7 t/ha) was obtained at 87 kg/ha of N with split application 1/2 at planting, ½ at knee height. This result is more than three times of the average sorghum yield in Ethiopia which is not more than 1.0 t ha-1 (CSA, 2000), and it is also significantly higher than world average which is about 2.3 t ha-1 (Benti, 1993).

Table 3: Effect of split application of nitrogen fertilizer on sorghum yield and yield related components 2013

Treatments code	Number of tiller	Grain yield (kg ha-1)	Stover yield (kg ha-1)
1	1.07^{d}	1792.3^{d}	4885.9^{e}
2	1.30^{cd}	2296.4^{c}	6992.6^{d}
3	1.67^{bc}	2482.6^{c}	7291.8^{cd}
4	1.27^{cd}	2449.8^{c}	7431.1^{bcd}
5	1.80^{b}	2356.6^{c}	7766.0^{bcd}
6	1.90^{ab}	3153.1^{b}	7880.0^{bcd}
7	1.80^{b}	3151.1^{b}	8456.3^{abcd}
8	1.60^{bc}	2449.0^{c}	8995.6^{abc}
9	2.27^{a}	3652.6^{a}	9225.2^{ab}
10	1.53^{bc}	3041.8^{b}	10297.0^{a}
CV	15	8.6	13.7
LSD (0.05)	0.04	304.26	1864.0

6 Conclusions

In the study district sorghum has wide coverage with stunted growth and low yield, less than 1 ton. Due to this the administrative bodies have been trying to convince farmers not to grow sorghum in the area. Their intension was to change it with other productive crops. But for long time this could not be possible as farmers have high attachment with sorghum cultivation with different reasons. First of all, farmers do not invest high labour and inputs for sorghum, they plant and back for harvest. Secondly the crop has different uses like to make local beer, local bread we call it 'Enjera', and the stover is important for their livestock feed. So, if farmers continue to grow sorghum cultivation. The only option is to improve its production through management, improved seed and input use. Fortunately, Gondar Agricultural Research Centre, with nutrient uses and improved managements, makes it possible to achieve high production of sorghum The Centre demonstrated widely this achievement for farmers on large plots, and the farmers' response were encouraging, they were happy and promised to adopt the technology. Further research on scale up the technology is necessary for a wide dissemination.

Figure 1: N split application on a sorghum experiment under management inputs

NOTE*: The data presented in this report are currently being elaborated for scientific publication, thus some of them are not final. The aim of this report is to summarize the nature and quality of the activities conducted and of the dataset generated, and to illustrate the main results obtained.*

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