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Efficiency of Different N, P, K Fertilizer Application Methods in Sorghum to Optimize Marginal Land Productivity

Nyo Nyo Mar[1], Khinezar Linn[2], Hnin Pwint Wai[3], Hla Mon[4], Aye Aye Soe[5], Myat Minn[6]
[1,2,3,4,5,6]Biotechnological Research Department, Ministry of Education, Kyaukse, Mandalay, Myanmar (+95)
nyonyomar1@gmail.com, khinezarlinn9@gmail.com, mhpw83@gmail.com, mahlamon@gmail.com, aasoe@gmail.com

Abstract— *Sorghum is the fifth important cereal grain crop in the world and reportedly feed over 500 million people on a daily basis in the developing world providing dietary starch, dietary protein and some vitamins and minerals. Sorghum has a high yielding potential, comparable of rice, wheat and maize so that it has been used for substituting rice in some mountainous area of Myanmar. As feedstock for fuel ethanol, sweet sorghum is a high biomass and sugar yielding crop with high photosynthetic efficiency and has the potential of becoming a useful energy crop. In dry zone area of Myanmar, sweet sorghum is also a promising new crop for bioethanol production. Myanmar's local sorghum variety, Shweni-15, was cultivated in this experiment for two years, 2017 and 2018 with different fertilizer application methods (placement and broadcast) for P and K with the rate of 40kg/ha for each together with two split application of normal urea with the rate of 90kg/ha has been used. The experiment was carried out in randomized complete block design with three replicates. Soil organic matter analysis, moisture, pH, N, P, K assimilation and texture of soil were tested. The purpose of this research is to study the response of sorghum variety to N, P, K fertilizers in difference application methods for better soil, water and nutrient management practices in marginal land area.*

Keywords— *Bioethanol, biomass,nutrient, marginal, sorghum.*

I. INTRODUCTION

Sorghum, *Sorghum bicolor L. Moench*, is known by common names such as milo, kafir, and guinea corn and originated in north-eastern Africa (Ethiopia, Sudan, and East Africa) where the greatest diversity of both wild and cultivated species occurs. Sorghum reached to Myanmar from India since 1856 and now it becomes one of the leading cereal crops after rice, maize and wheat in Myanmar and released 21 varieties. Over 50% of the sorghum grain produced in the country is for human consumption and it is staple food in the rice-deficient central dry zone and mountainous area. Total currently sown area of sorghum is Myanmar is about 226ha in 2014 and produced 229,000MT (MOALI, 2014).

The crop is mainly grown in tropical and subtropical areas where agro climatic conditions such as rainfall, soil and temperature are variable. Much of the crop is produced in the more marginal and stress-prone areas of the semi-arid tropics, mainly on smallholdings. It is also widely grown in temperate regions and at altitudes of up to 2300 m in the tropics. It can tolerate high temperature throughout its life cycle better than any other crop.

Although sorghum can respond to good moisture supplies, it is nevertheless one of the toughest, drought tolerant crops available and this tends to maintain its popularity in the regions where the weather is very unpredictable.

Sorghum has many good characteristics such as a drought resistance (Tesso, 2005), water lodging tolerance, salinity resistance. Moreover, it is not required much inputs and can be grown on marginal and degraded lands contributing to increase agricultural production, crop diversification and better environment. It is also a major feed and forage crop for feed, food, fiber and fuel.

Most of the sorghum produced is consumed as human food in the form of *roti bhakri* or *chapathi* in India and *ugali, kisra, injera, to,* etc, in Africa. Main traditional uses of sorghum encompass utilization of grain for food and stalks as fodder. The possible promising alternative food products from sorghum are baker products, maltodextrins as fat replacers in cookies, liquids or powder glucose, high fructose syrup and sorbitol. The industrial products made from sorghum grain include alcohol (potable grade) and lager beer (Swa, 89). Beside for human food and as feed for animals: the planat stem and foliage are used for green chop, hay, silage, and pasture, IN some areas the stem is used as building material, and plant remains (after the head is harvested) may be used for fuel.

There are "specialty" sorghums, such as pop sorghum and sweet sorghum that can be parched and eaten. These specialty sorghums are frequently grown as borders of large fields. The quality of sorghum protein is deficient, like that of several other cereal crops, because of a low concentration of the essential amino acid, lysine (Lel, 1985).

Other technologies such as production of glucose, maltodextrins, high fructose syrup and cakes from sorghum are yet to be scaled up. The products are then fed to beef and dairy cattle, laying hens and poultry and pigs, and are used in pet foods. The juice from sweet sorghum stalks is fermented to produce ethanol (biofuel) and other sweet sorghum products like syrup and *jiggery* have received good attention in production of food products like sweets and ready to serve foods (Swa, 1986).

Beside its special quality for foods, feed and fiber, sorghum has become more attractive to breeders due to its capacity to provide renewable energy products. The adoption of bioenergy will mitigate the effects of elevated greenhouse gases in the environment, it will also diversify the energy portfolio, enhance energy security (Ver, 2007), reduce dependence on the oil producing countries which are known

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for their political instability, and may stimulate third world economic development.

In short run, bioethanol and biodiesel are considered the most promising transportation fuels to replace diesel, gasoline or petroleum. Biodeisel is produced from plant-based oils or fats that is produced from oil-containing seeds of either soybean (*Glycine max* (L) Merr.), sunflower (*Helianthus annus* L.) or canola (*Brassica napus* L.) and bioethanol can be produced by fermenting sugars mostly glucose and sucrose. These sugars can be obtained directly from juice of sweet sorghum or sugarcane, through conversion of starch of sorghum or maize grain, or through conversion of cellulose and hemicellulose from stovers of maize and sorghum.

Sweet sorghum is similar to grain sorghum but features more rapid growth, higher biomass production,, wider adaptation, and has great potential for ethanol production, Sweet sorghum is more water use efficiency and can be successfully grown in semi0arid tropics, where other crops such as maize fail to thrive (Bel, 2008). Sweet sorghum has Sugar-rich stalks (16-23% Brix). Sorghum like sugarcane is a C4 plant characterized with high photosynthetic efficiency. Sugar yield is the major breeding objective in sweet sorghum. Aitken in 2006 defined sugar yield as the function of cane yield and recoverable sucrose content from the harvested cane (Ait, 2006).

Also like grain sorghum, starch reserves in sweet sorghum grain can be used for ethanol production. It is needed to evaluate grain starch composition in different sorghum cultivars because ethanol production efficiency from starch is a function of hydrolysis temperature, and resistant starch content in grain (Sha, 2005). Determination of srach composition in sweet sorghum seed is also important because some sweet sorghum varieties may have potential as dual-purpose crops yielding both sugar-rich extractable juice and grain. With upwards of 4000 sweet sorghum cultivars distributed throughout the world (Gra, 2004).

Sorghum is a species showing extensive genetic variation, including drought and heat tolerant genotypes, which enable the usage of marginal land that is not suitable for cultivating the other crops. Moreover, competition between the use of land for food or energy is less because the grains can be used for food or feed while stems can be used for biofuel production (Amu, 2009).

Sorghum is mainly grown on low potential, shallow soils with high clay content, which is not usually suitable for the production of maize. Sorghum usually grows poorly on sandy soils, except where heavy texture subsoil is present. Sorghum is more tolerant of alkaline salts than other grain crops and can therefore be successfully cultivated on soils with a pH (KCL) between 5 and 8. Sorghum can better tolerate short periods of water logging compared to maize. Soil with a clay percentage between 10 and 30% are optimal for sorghum production (Ric, 2010).

In Myanmar, cereal crop such as paddy and maize are very important not only for local consumption but for export. Pulses, oilseed crops and major group in rice based cropping system accreting to the nature of crop, soil and weather relationship. Other crops needed to be improved to attain food security and raw materials for industry.

Sorghum has an ability to cope with many types of stresses, including heat, drought, and salinity and flooding, in arid and semi-arid regions, this crop is usually affected by drought stress at the post flowering stage of growth. To face the worsening conditions brought about by climate change and variability, sorghum was sought that would require less agricultural inputs, being drought tolerant, has a good adaptability and with high economic value.

II. Materials and Methods

Sorghum breeding is of importance in order to improve productivity and quality, especially in lines with making optimal use of marginal or unproductive land. The experiment was carried out in the research field (Tonelone) of Biotechnological Research Department, Kyaukse District of Mandalay Region, Myanmar. It is situated at an elevation of 268 feet above mean sea level with 21º 36’N latitude and 96 º 08’ E longitudes. That place is un- usual agriculture lands not only because of low fertility but also cause of geographical condition, dry zone and low moisture holding capacity, high evapotranspiration. The soil types of experimental area were measure at Department of Agriculture (Land Use), Ministry of Livestock, Agriculture and Irrigation. The climatic data such as average monthly rainfall, minimum and maximum air and soil temperature, humidity, etc. were recorded throughout the experimental time.

Local cultivar sorghum (Shweni-15 Var.) which was obtained from the Department of Agriculture Research (DAR) was used for this study. Evaluation of for fertilizer management approach for sweet sorghum has been carried out in this research. In the year 2016, nitrogen use efficiency of sweet sorghum plants was done by using ^{15}N tracer in three difference dosages (30, 60 and 90 kg/ha respectively) with three split application method. According to this experiment, nitrogen fertilizer rate 90kg/ha was the best rate for sorghum variety for this area. Therefore, continuous experiment with ^{15}N at 90kg/ha in two split application was carried out in 2017.

In 2018, two fertilizer application methods (placement and broadcast) for P and K with the rate of 40kg/ha for each together with two split application of normal urea with the rate of 90kg/ha has being cultivated in randomized complete block design with three replicates. The plots sizes were $49m^2$ with 2m difference between each. The field layout design was as shown in figure 1 where P stands for placement application, B for broadcast application and C is for control respectively.

In placement treatment, the fertilizer P and K were applied in bandage form and sown beside the plant about 4-5 inches depth of the soil surface. For urea application, half of the total applied dosage was firstly feed at the plant’s vegetative stage and the second time was applied at its flowering stage or early soft dough stage.

The agronomic data such as plant height, panicle length, number of panicle per plant, number of leaves per plant, leaves weight (fresh/dry), grain weight (fresh/dry) and stover weight (fresh/dry) were collected. According to the recorded data, the evaluations of results (yield, grain harvest index) between two different fertilization methods were calculated.

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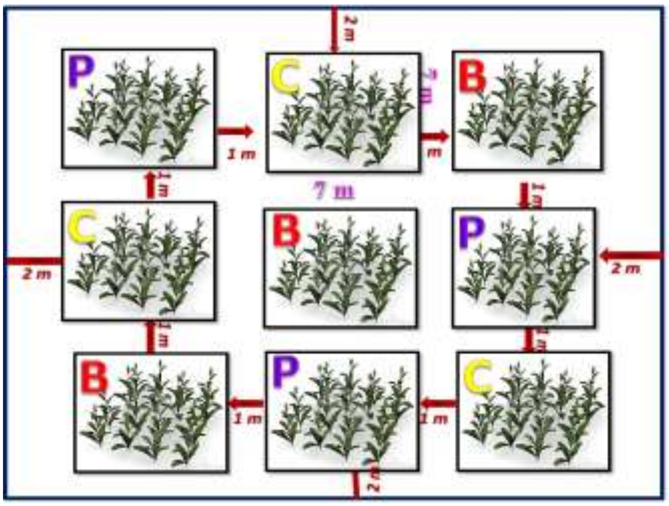

Fig. 1. Field layout of the experiment.

III. Results and Discussion

There was a positive response to the different fertilizer application in both studies, with a right time, right apply and right dosage needed for optimum yield when soil test levels of marginal land were in the low rather than the medium fertile range. There was no interaction between: (1) tillage system and rate of P applied, (2) tillage system and P placement, and (3) rate and placement of P fertilizer (Alston A.M, 1980). To access the correct quantity of fertilizer to be applied for optimal yield, soil samples should be taken according to the recommendations of an accredited soil laboratory. Fertilizer recommendations made according to the soil analysis should be applied accordingly.

Based on FAO statistical data, there are about 247280 tons of sorghum were produced in 2016 and this representing a sharp increased over the last 20 years in Myanmar. The use of phosphate fertilizer has promoted changes in phosphorus fractions and availability in soil that highlights the requirement of more studies to understand phosphorus dynamics in soil and to develop cultivation strategies to increase crop grain yield under phosphate fertilization (Grant, 2001).

As shown in table I, the soil analysis result of experimental field, revealed that the soil is extremely alkaline with pH value of 9.23 where available N, P and K ratio were under limited condition. Results of assessing potentials of marginal lands suitable for bioenergy production vary widely. Particularly, sites which can be classified as "marginal" offer potentials for biodiversity protection and their use might generate new conflicts, e.g. with nature conservation (Dauber and Miyake, 2016; Miyake et al., 2015; Plieninger and Gaertner, 2011).

TABLE I. Soil profile of experimental site.

No	pH	Tot. N (%)	Ava. P (ppm)	Ava. K2O (mg/100g)	Exchang. K (me.100g)	Soil Texture
1	9.2 3	0.25	0.17	18.33	0.39	Silty Clay Loam

According to the experimental result from 2017, urea with the dose of 90kg/ha was the best rate for sorghum variety in this marginal land amongst 30kg/ha and 60kg/ha as its yield, grain harvest index and agro-characteristics collection.

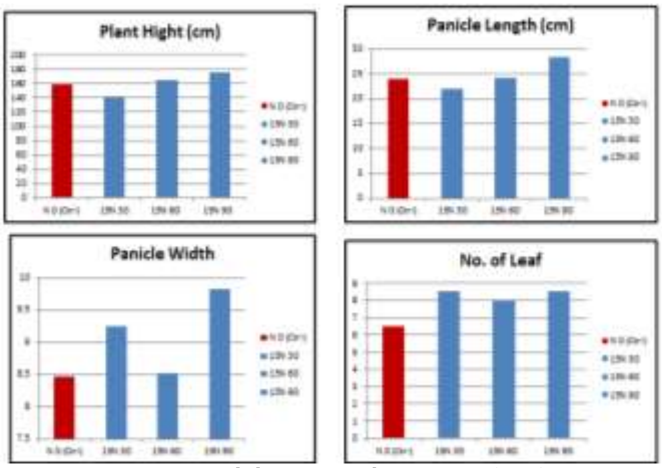

Fig. 2. Recorded agronomic characteristics (2017).

Plant height, panicle length, panicle width, number of leaf per plant, stover fresh weight, stalk fresh weight and grain fresh weight were recorded and the results were shown in bar chat for comparison in Figure 2. Grain harvest index was significantly high in 90kg/ha urea treatment other than 30kg/ha and 60kg/ha. So, this rate of urea application was selected for further experiment.

TABLE II. Grain Harvest Index (%) of three treatments (2017).

Treatments	Harvest Index (%)
N-0	13.75
N-30	17.42
N-60	16.22
N-90	20.86

In 2018, the sorghum field was feed with different fertilizer application methods for P and K whose rate is 40kg/ha each together whereas only one dose of urea 90kg/ha was applied in two spited times, vegetative stage and reproductive stage. In both treatment options, crops generally respond well to fertilizer inputs and can provide interesting economic yield benefits.

Plants treated with P and K placement near their feet showed higher in plant height, number of leaves per plant, panicle length and width and also in stalk weight. On the other hand, fertilizer application by hand broadcasting revealed crop improvement than the control one whose agro characteristics were at lowest values. Marginal lands have been frequently considered as potential alternatives for producing bioenergy from biomass.

In the result of plant width, the highest mean value was observed in placement treated plants followed by broadcasted plants where control plants have longer panicle length but they are smaller in width that mean they are not filled with seeds. Table III is showing some agronomic characteristics recorded from the treated plants in 2018.

TABLE III. Agronomic characteristics of plants (2018).

Treat-ment	Plant Height (cm)	No. of Leaves	Panicle Length (cm)	Panicle Width (cm)	Stalk Weight (g)
P	186.35	14	20.667	12.16	239
B	175.97	16	19.79	11.2	200
C	170	12	20.957	8.79	168.59

For grain yield evaluation, broadcasting may produce higher yields if enough extra P is applied to make up for increased tie-up, it's doubtful whether limited-resource farmers should be aiming for maximum yields (J. C. Zadoks, 1974). Most of them face several yield-limiting factors ranging from marginal land to insufficient capital. At this case, the localized placement method greatly reduces the opportunity for P tie-up by minimizing the soil's contact with the fertilizer. It also results in a high enough concentration of P to overcome the tie-up ability of the soil immediately surrounding the fertilizer (Human Info NGO). The following chart revealed that localized placement method of fertilizer application was best fitted practices for high sorghum yield in marginal land.

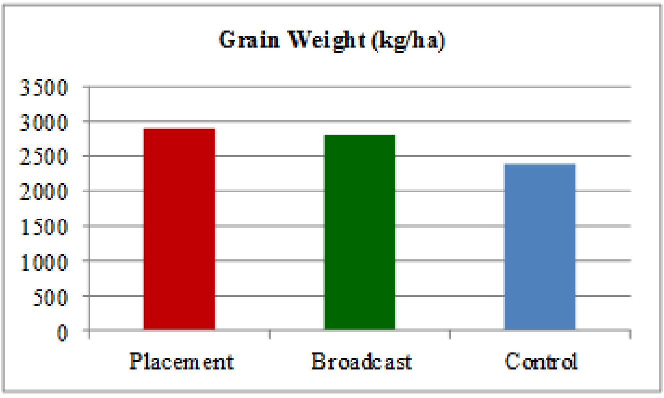

Fig. 3. Gain weights from different fertilizer application methods.

IV. Conclusion and Recommendations

Sorghum and millets will continue to play a key role in providing food security in subsistence cropping systems of Asia and Africa, and in improving economic returns to large farmers in the assured rainfall regions of the world. Research and extension activities towards crop improvement, intensified cropping systems and improved management of soil, water, nutrients and weeds will help produce higher yields (P.V. Vara, 2011). With an increasing competition between traditional agriculture for food and feed production and production of renewable resources for bioenergy or biomaterials, both unconventional land use systems as well as use unconventional land gain more and more attention in Europe but also worldwide (Fischer, 2009; Popp, 2014; Rathmann, 2010).

The effectiveness of both fertilizer application methods was obvious in sorghum yield at marginal land and hence, this experiment can improve the role of marginal land in overcoming biofuels land use controversies. However, knowledge of the extent, location, and quality of marginal lands as well as their assessment and management are limited and diverse (Shujiang, 2013).

In order to enhance marginal land productivity as well as supporting farmers' interest on sweet sorghum cultivation, this research was carried out. According to the recorded data and calculated results, placement of P and K fertilizer vicinity of the plant can effectively improve fertilizer uptake and give better yield potential. On the other hand, split application of urea to the plantation can not only provide information of right dose and right timing of nitrogen fertilizer application but also can share knowledge and best fitting fertilizer application methods for local sorghum cultivars especially those who are facing low productivity in marginal land area.

As the localized placement method is usually the best ones for limited-resource farmers whose capital, management, and level of other limiting factors point toward using low to moderate rates of chemical fertilizers, further investigation of reducing the rate of the fertilizer with this method should be conducted. Bioethanol and biochar production from sweet sorghum can become an important concern in Myanmar and interest renewable energy source as well as better utilization of marginal land for productivity.

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