International Journal of Modern Agriculture, Volume 9, No.4, 2020
ISSN: 2305 - 7246

NUTRIENT UPTAKE, GRAIN AND STOVER YIELD OF PEARL MILLET (*Pennisetum glaucum* L.) AT DIFFERENT LEVELS OF MINERAL FERTILIZER AND FOLIAGE OF *Jatropha curcas* L

Nuraddeen Abdullahi Aliyu[1], Roslan Ismail[2], Martini Mohammed Yusoff[3], Mohd Firdaus Mohd Anuar[4], Adamu Garba K/Naisa[5]

[1,2,4] Department of Land Management, Faculty of Agriculture, University Putra Malaysia, UPM Serdang, Selangor,

[3] Department of Crop Science, Faculty of Agriculture, University Putra Malaysia, UPM Serdang, Selangor, Malaysia

[5] Department of Geography and Regional Planning, Federal University Dutsinma, Nigeria

Corresponding author:

Nuraddeen Abdullahi Aliyu
Department of Land Management, Faculty of Agriculture, University Putra Malaysia, UPM Serdang, Selangor

Abstract

Foliage of *Jatropha curcas* L. as soil amendment to improve pearl millet productivity was evaluated under field conditions at Kadawa (11.650°N & 8.450°E) Nigeria. The treatments consisted of 3 rates of jatropha foliage (0, 5t/ha and 10t/ha) and 3 rates of mineral fertilizer (0, half and full recommended rates of N-P-K. 60:30:30. Kg/ha). Experimental design was the randomized complete block with three replications. Using standard procedures, the soil and jatropha foliage were characterized for nutrient elements content, while the uptake of nutrients (N.P.K) was calculated by multiplying nutrient concentration (%) and the corresponding yield (kg/ha). Results showed that the native soil was of low fertility status and the foliage was a suitable organic amendment that can be incorporated in to soil. Mineral fertilizer alone or in combination with the foliage significantly increased both grain and stover yields, while jatropha foliage alone did not achieve optimum yield levels. Also, nutrients uptake was significantly higher in plots treated with mineral fertilizer alone or in combination with foliage of jatropha. Generally, the complementary use of half recommended rate of mineral fertilizer and 10t/ha rate of jatropha foliage was always at par with the full recommended rate of mineral fertilizer in terms of yields and nutrients uptake. This suggests that farmers can establish jatropha plants around their fields to use the foliage along with lower rates of mineral fertilizer for enhanced pearl millet productivity

Keywords: Sudan Savanna, Super sosat, Agroforestry, N-P-K uptake, Recommended rate.

Introduction

Globally, pearl millet is ranked as the 5th most important cereal crop after maize, rice, wheat and sorghum. It is mostly cultivated as a rainfed crop in the Arid and Semi-Arid areas of Africa and Asia where annual rainfall is as low as 200-600mm (Reddy et al., 2016). In West Africa, where the crop originated (>4000 years ago), it can be grown in agroforestry systems together with trees and treelets such as Faidherbia albida,Acacia albida, Gliricidia spp, Jatropha curcas e.t.c. and yields are reported to be increased by >36-169% due to enhanced soil nutrient level , more available water and better physical properties of soil (Scholl and Nieuwenhuis, 2007; Mason et al., 2015). Pearl millet is cultivated in countries such as India, China, Nigeria, Sudan, Egypt, Russia e.t.c. Reddy et al. (2017) reported that the grain of pearl millet is nutritious and contains approximately 11-19% protein, 60-78% carbohydrate, 3-4% oil as well as good quantities of iron and phosphorus. Scarce economic and technological support have restrained increased production of the crop, so that low productivity as a result of little investment on pearl millet research programs have led to low use of agronomic techniques such as fertilizer use and mechanization (Macauley and Ramadjita, 2015).

Consequently, FAO (2017) stated that the crop keeps recording the lowest global average yield (0.8t/ha), in the last 5 decades in comparison to maize (4.0t/ha), rice (3.8t/ha), wheat (2.6t/ha) and sorghum (1.5t/ha). In 2018, the United Nations' food and Agricultural Organisation approved 2023 as the international year of millets in order to increase the global awareness of the numerous benefits of pearl millet (Hans, 2018). Also, Gill (2018) reported that the year 2018 was declared by India as the national year of millets while millets were featured in African Agricultural initiatives such as Technology for African Agricultural Transformation (TAAT) and Adaptation of the African Agriculture (AAA) which are funded by the African Development Bank (AfDB). All these are targeted towards increased millets productivity.

Divya et al. (2017) explained that the major reasons for low yields in pearl millet production are water and nutritional stresses. Maman and Mason (2013) stated that the addition of good quality organic amendment to soil increases yield of pearl millet. One way of mitigating the problem of nutrient depletion and that of high cost of fertilizers in Nigerian savanna is to seek for, and use locally available resources that are both cheap and accessible. In Nigeria, pearl millet is highly consumed by the community (over 40 million people) to the extent that annually, over 4 million tonnes are consumed, while the country could only produce less than 2 million tonnes (FAO, 2017; Cheng and Catherine, 2016; Miller, 2016). This clearly highlights the gap between local demand and production level of such an important crop in Nigeria. Essentially, millet is mostly cultivated in the dryer Northern parts of Nigeria. Nutritional stresses due to low soil fertility are among the major constraints to higher pearl millet yields in these areas (Maryam et al., 2017). In order to boost the productivity of the crop, combined use of both mineral and organic resources have been found to be effective for sustained and increased performance (Divya et al., 2017).

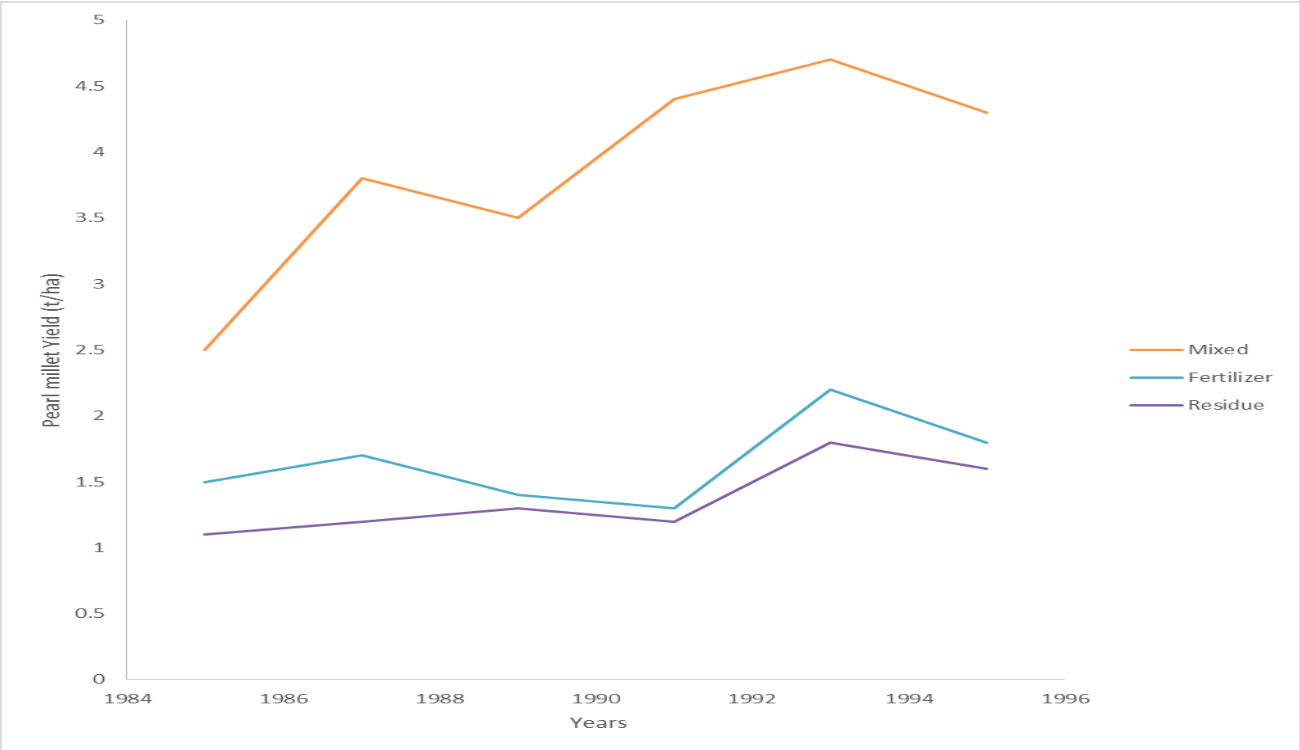

Figure 1: Increase in pearl millet yield (1985-1995) from use of plant residue and fertilizer supplied separately and mixed (ICRISAT, 1997)

The observation that jatropha foliage has good amount of total nitrogen (3.4%), and low lignin (11.1%), polyphenols (0.7%) and C:N ratio (12.9) makes it suitable for use as soil amendment (Victor et al., 2010; Giller, 2001; Palm et al, 2001). Moreover, most research work on Jatropha have focused on its potential as a biofuel plant for sourcing energy, while others that relate to soil and plant development gave more emphasis on the use of its seed cake, instead of the unprocessed basic parts (foliage) of the plant that can be suitable organic resources for improving soil conditions. These foliage is indeed cheap and easy to be accessed by local small scale farmers.

The fact that in the Nigerian sudan savanna, many poor farmers do fence their fields with Jatropha curcas treelets and pearl millet is an important and widely grown crop in the area triggered this study to determine the effect of different rates of mineral fertilizer and foliage of Jatropha curcas on the yield and nutrient uptake of pearl millet in Sudan Savanna of Nigeria.

MATERIALS AND METHOD

The trial was conducted at the research farm, Kadawa (11.650°N and 8.450°E). The area lies within the sudan savanna of Nigeria. Annual rainfall is about 700mm. The soil is loamy sand in texture and described as typic ustropepts by soil survey staff (1975). Some physicochemical properties of the soil are shown in table 1. The trial was carried out under rainfed condition. Treatments consisted of 3 rates of Jatropha foliage (0, 5t/ha and 10t/ha) and 3 rates of mineral fertilizer (0, half recommended rate and full recommended rate of 60kgN/ha, 30kgP_2O_5/ha and 30kgK_2O/ha). These rates were combined and allocated to field plots in a randomized complete block design (RCBD) replicated 3 times. The 9 treatments are as follows:

1. Absolute control (J1F1)
2. Half recommended mineral fertilizer (J1F2)
3. Full recommended mineral fertilizer (J1F3)
4. 5t/ha foliage of jatropha only (J2F1)
5. 5t/ha foliage plus half recommended mineral fertilizer (J2F2)
6. 5t/ha foliage plus full recommended mineral fertilizer (J2F3)
7. 10t/ha foliage of jatropha only (J3F1)
8. 10t/ha foliage plus half recommended mineral fertilizer (J3F2)
9. 10t/ha foliage plus full recommended mineral fertilizer (J3F3)

Foliage of jatropha (soil amendment) was incorporated at 3 weeks before sowing. Foliage was incorporated by burying into furrows. Gross plot size was 4.5m (0.75m x 6 rows) by 6m. Inter and intra row spacing were 75cm by 25cm respectively. All P and K mineral fertilizers were applied at 2 weeks after sowing while the N was split applied at 2 weeks after sowing (using N.P.K 15:15:15) and at 6 weeks after sowing (using urea). Weeding was done manually with hoe at 2 days before sowing, 2 weeks after sowing and 6 weeks after sowing. Harvesting was carried out when the crop attained physiological maturity. Net plot harvest was left to sun dry for 3 weeks. Threshing was after sun drying. Grains were separated by threshing and winnowing to obtain clean grains, then for each plot, the grains and stover were separately weighed.

Test crop was pearl millet (super sosat variety). Grain and stover yields were determined by weighing net plot yields and subsequently converting them into kg/ha basis. Nutrients (N.P.K) uptake was calculated by multiplying concentration (%) in sample (grain/stover) and the corresponding yield (kg/ha). Soil and jatropha foliage samples were taken before the commencement of the experiment.

Soil, foliage, grains and stover analyses were conducted using standard procedures as detailed by Anderson and Ingram (1994) and Okelabo et al. (2002) as follows:

Soil was sampled from each plot at a depth of 0-20cm (zig-zag pattern). Afterwards, equal amounts of soil samples were mixed to form one composite sample per plot. Composite soil samples were air-dried and crushed to pass through a 2mm sieve. 3 sub-samples from each composite sample were then analyzed for some physical and chemical properties. Particle size distribution was by hydrometer method using 5% calgon as dispersant and textural class determined via USDA textural triangle. Electrical conductivity (EC) and soil reaction (pH) by using EC and pH meters respectively in 1:2.5 soil/solution ratio. Organic carbon was by the wet oxidation method of walkley and black (Nelson and Sommers, 1982). Total nitrogen was by the microkjeldahl method after wet oxidation of organic matter. Free ammonia was liberated from the digest by steam distillation in the presence of excess alkali. The distillate was collected in a receiver with excess boric acid (indicator pH 4.5). Total nitrogen was then determined by titration. Available phosphorus was by Bray no. 1 method (0.025N HCl +0.03N NH_4F) as described by Bray and Kurtz (1945). Exchangeable cations and CEC by 1N NH_4OAC at pH 7. Exchangeable K was determined by flame emission spectroscopy.

For plant samples, the jatropha foliage was randomly taken from 10 plants at 4 weeks after the on-set of rains. Foliage was cut into pieces for homogenization, mixed, air-dried for 3 weeks, ground and passed through 2mm sieve. Also, dried grains and stover samples were taken from each plot after harvest. The samples were ground and screened through 2mm sieve. Three sub-samples were taken for determination of nutrients concentration. Total nitrogen was determined by microkjeldahl procedure (Bremner, 1965). Total phosphorus using wet digestion was determined by the vanadomolybdate phosphoric yellow color method (Kalra and Maynard, 1994), while potassium was determined using flame photometry after wet digestion (Anderson and Ingram, 1994). Organic carbon was by ash method as described by Okelabo et al. (2002). Lignin in foliage was determined based on the acid detergent fibre (ADF) method by boiling with sulfuric acid and the lignin removed by oxidation with buffered permanganate solution, while polyphenols determination was done with 50% methanol (at 80^0C) by using tannic acid as standard (Anderson and Ingram, 1993)

All data were subjected to analysis of variance and means separation was by Duncan multiple range test (DMRT) at 5% level of significance (LOS) using statistical analysis system (SAS, 2013) version 9.4. Percentage increase in yield was calculated by using the following expression:

Yield increase (%) = $(Yield_{treatment} - Yield_{control}) / Yield_{control} \times 100$.

RESULTS AND DISCUSSION

Characterization of soil and jatropha foliage

Data presented in table 1 showed that the soil at the study site was acidic, low in organic carbon (0.47%), low in total nitrogen (0.09%), low in available phosphorus (6.13 mg/kg) and low in cation exchange capacity (3.7cmol/kg). Therefore, addition of nutrients to the soil will likely lead to higher crop yields (Horneck et al., 2011). Soils of the Sudan Savanna are known to be low in fertility due to nutrient mining and lack of inherent capacity to hold and supply plant nutrients (Adamty, 2016; Jones et al., 2013; Sanginga and Woomer, 2009).

Table 1: Selected soil physicochemical properties of the experimental site

Soil property	Value
Sand (%)	84
Silt (%)	14
Clay (%)	2

Texture	Loamy sand
pH (H_2O)	6.37
E.C. (ds/m)	0.04
Organic carbon (%)	0.47
Total nitrogen (%)	0.09
Available Phosphorus (mg/kg)	6.13
Exch. K (cmol/kg)	0.15
CEC (cmol/kg)	3.7

The chemical composition of jatropha foliage (table 2) makes it suitable for use as organic amendment. Palm et al. (2001) and Giller (2001) provided a guide to the use of different organic resources as soil input by considering the material's quality in terms of macronutrients, lignin and polyphenol contents. Organic materials with >2.5% nitrogen, <15% lignin and <4% polyphenols can be incorporated directly into soil. Those having ≤2.5% nitrogen and ≥15% lignin are to be surface applied for erosion and water control. When the organic material has >2.5% nitrogen and >15% lignin or >4% polyphenols, then it should be mixed with fertilizer or quality organic matter. A material with ≤2.5% nitrogen but <15% lignin can be mixed with fertilizer or added to compost. For the inceptisols of Sudan Savanna, application of quality organic inputs can greatly improve and sustain soil fertility particularly in the long term. Moreover, Chaudhary et al. (2014) indicated that jatropha foliage has proved to be a promising source of mineral nitrogen and carbon mineralization.

Table 2: Some chemical properties of the Jatropha foliage

Property	**Value**
Total nitrogen (%)	3.03
Phosphorus (%)	0.25
Potassium (%)	1.8
Organic carbon (%)	43.6
Lignin (%)	12.5
Polyphenols (%)	0.47
C:N ratio	14.4

Response of pearl millet to applied nutrients and amendment

Table 3 shows the influence of the various treatments on grain and stover yield of pearl millet:

Table 3: Response of pearl millet yield to mineral fertilizer and foliage of Jatropha

No.	**Treatment description**	**Grain yield (kg/ha)**	**Stover yield (kg/ha)**
1.	Absolute control	0967c	4791cd

2.	Half recommended mineral fertilizer	3456ab	6682b
3.	Full recommended mineral fertilizer	3924ab	8807a
4.	5t/ha foliage of jatropha only	1630c	4546d
5.	5t/ha foliage plus half rec. mineral fertilizer	2637bc	6250bc
6.	5t/ha foliage plus full rec. mineral fertilizer	2555bc	6724b
7.	10t/ha foliage of jatropha only	1792c	5303bcd
8.	10t/ha foliage plus half rec. mineral fertilizer	3842ab	6818b
9.	10t/ha foliage plus full rec. mineral fertilizer	4493a	9129a
	C.V. (%)	16.7	7.6
	SE	496.4	498.6

In each column, means carrying the same letter(s) are not significantly different according to DMRT at 5% LOS.

From table 3, grain yield ranged between 967-4493 kg/ha. The yield of control treatment (967kg/ha) was significantly ($p<0.05$) lower than treatments having mineral fertilizer with or without 10t/ha jatropha foliage. Highest yield was recorded in treatment with full mineral fertilizer plus 10t/ha jatropha pruning. Treatments with only jatropha foliage were statistically at par with the control treatment. 5t/ha jatropha foliage plus mineral fertilizer (half or full recommended rate) was also at par with the control treatment. Grain yield of full recommended rate of mineral fertilizer was statistically the same as obtained in treatment with 10t/ha jatropha foliage plus half recommended rate of mineral fertilizer. Brady and Weil (2008) have shown the synergy in combining organic nutrient sources with mineral fertilizer for increased and sustainable production of pearl millet in Africa. Tarfa et al. (2001) and Bhuva et al. (2018) reported increased grain and stover yield with increasing mineral fertilizer and trees foliage application. It can also be observed that the use of foliage of jatropha at lower rate (5t/ha) did not significantly produce more yield levels when compared with the absolute control. This suggests that higher amounts (perhaps ≥10t/ha) of the jatropha foliage are required in order to significantly boost yield levels of the crop. Brady and Weil (2008) recommended the application of large amounts of organic wastes and manures to help remedy soil fertility constraints in the study area. Jatropha foliage (alone) did not achieve optimum grain yield levels.

Full rate of mineral fertilizer plus 10t/ha jatropha foliage significantly ($P<0.05$) yielded the highest amount of stover (9129kg/ha) and was at par with full rate of mineral fertilizer. In particular, the treatment with 10t/ha jatropha foliage plus half recommended rate of mineral fertilizer was significantly superior in stover yield than all other treatments except those with full recommended mineral fertilizer. The treatments having foliage of jatropha only did not relatively produce much stover. Generally, all treatments that have mineral fertilizer only or in combination with foliage of jatropha were superior than other treatments. This is suggesting that the use of jatropha foliage to improve pearl millet productivity in the study area has to be carefully complemented with application of mineral fertilizer, so that all organic and inorganic inputs are managed in accordance with sound agronomic principles (Vanlauwe et al., 2010). Moreover, Divya et al. (2017) reported that the use of mineral fertilizer with organic input shows promise in maintaining high level of performance and greater stability towards crop production.

However, 5t/ha jatropha foliage increased the grain yield of pearl millet by at least 68% (figure 2). Moreover, the 10t/ha jatropha foliage alone increased grain yield by up to 85%. Traore et al. (2012) reported an increase of at least 52% in pearl millet yield by using jatropha oil cake as soil amendment in the Sahel. 10t/ha jatropha plus full recommended rate of fertilizer recorded the highest increase in grain and stover yields (365% and 91% respectively). The treatment with 10t/ha jatropha foliage plus half rate of mineral fertilizer had grain and stover yield increases of 297% and 43% respectively.

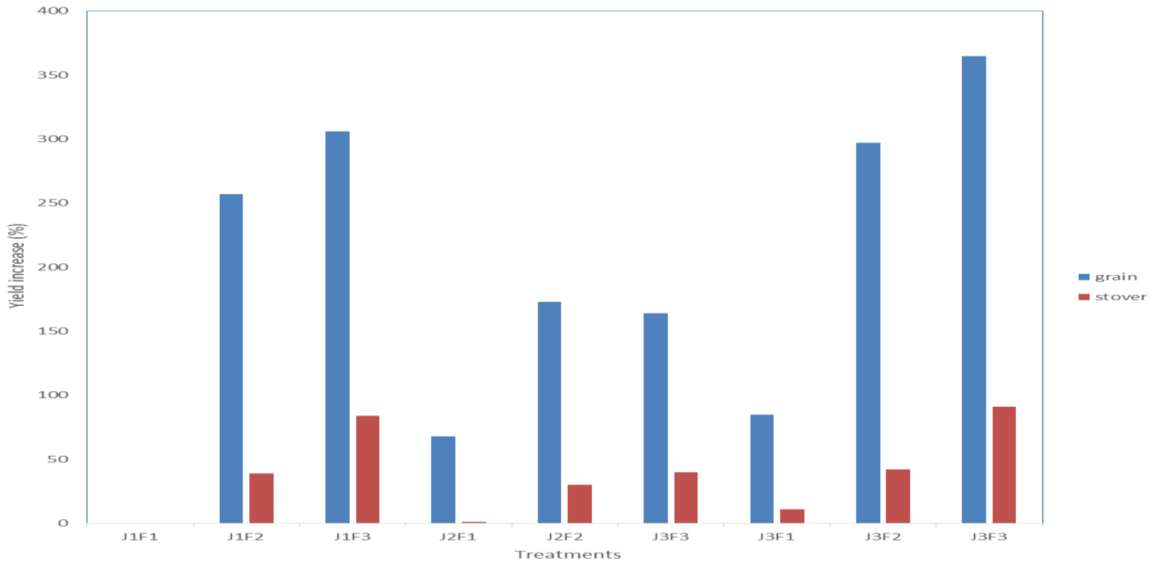

Figure 2: Increase (%) in grain and stover yield as influenced by treatments

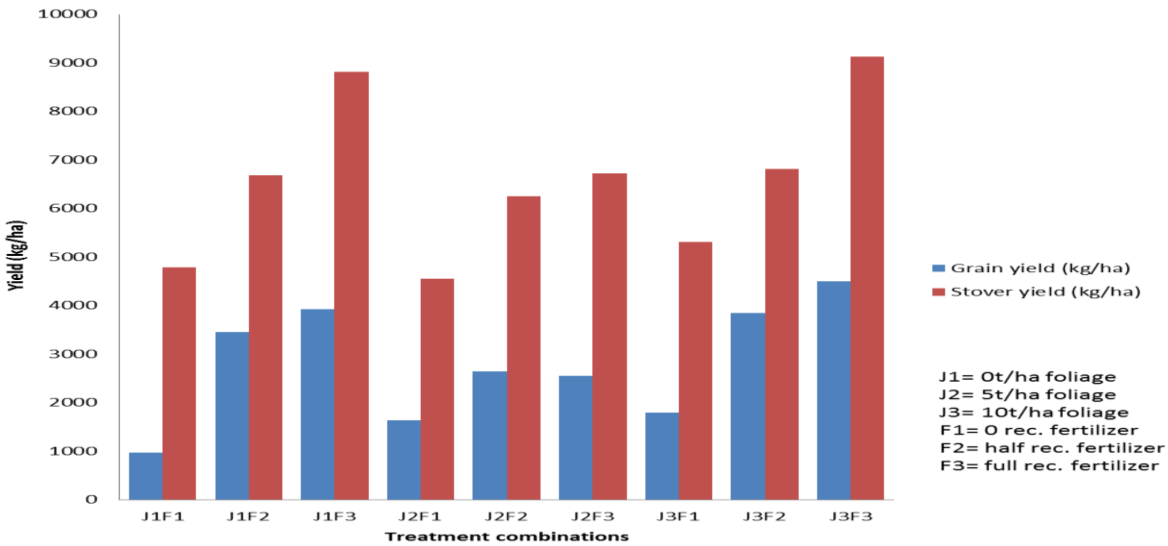

Figure 3: Effect of treatments on pearl millet yield

Influence of mineral fertilizer and jatropha foliage on uptake of nutrients (N.P.K.) in pearl millet

The effect of treatments on the grain uptake of nitrogen, phosphorus and potassium is presented in table 4:

Table 4: Effect of treatments on grain nutrients (N.P.K) uptake (kg/ha)

No.	Treatment description	N	P	K
1.	Absolute control	18.46c	2.11	04.40
2.	Half recommended mineral fertilizer	69.35a	6.77	16.24
3.	Full recommended mineral fertilizer	67.53a	7.78	17.97
4.	5t/ha foliage of jatropha only	27.61bc	3.15	06.74
5.	5t/ha foliage plus half mineral fertilizer	43.18abc	5.47	12.94
6.	5t/ha foliage plus full mineral fertilizer	57.18ab	5.36	13.09
7.	10t/ha foliage of jatropha only	27.93bc	3.16	08.72
8.	10t/ha foliage plus half mineral fertilizer	55.84ab	6.00	20.05
9.	10t/ha foliage plus full mineral fertilizer	67.39a	5.64	12.71
	C.V.(%)	16.5	17.5	15.3
	SE	7.9	0.9	1.9

In each column, means carrying the same letter(s) are not significantly different according to DMRT at 5% LOS.

From table 4, the least uptake of nutrients (N.P.K) was always observed in the control treatment. The result showed that grain N-uptake was significantly ($p<0.05$) superior in treatments having mineral fertilizer (with or without jatropha foliage). This is in accordance with the findings of Tarfa et al. (2001). Senthilkumar et al. (2017) concluded that fertilizer plus compost (5t/ha) is effective in improving nutrient uptake by pearl millet. Higher NPK uptake was also associated with compost (2.5t/ha) plus 100% fertilizer (Manjeet and Kumar, 2017). Nitrogen has been described by Foth (1990) as the most limiting nutrient in food crop production hence its uptake by plants is very critical and important. There was no significant difference among treatments with respect to grain phosphorus and potassium uptake. Hussain et al. (2008) did explain that nutrient uptake may or may not significantly increase with increasing supply of nutrients. Generally, nutrients uptake was observed to be highest in treatments having mineral fertilizer alone or in combination with jatropha foliage. It can also be observed that the treatment with half recommended rate of mineral fertilizer plus 10t/ha foliage of jatropha was always at par with the treatment having full recommended rate of mineral fertilizer. Tisdale et al. (2003) stated that the various interactions of many chemical, physical and biological processes in the soil influence the availability of nutrients to plants and that the uptake of nutrients by plants is genetically controlled even within varieties of a species. Marschner (2012) did also explain that nutrients uptake by higher plants is genetically determined and can differ within and between species of plants. Bender et al. (2013) stated that an understanding of nutrient uptake by particular species of crop plant is important in terms of how to fertilize it optimally.

Table 5 is the result of stover nutrients uptake. Control treatment was statistically poorer than all other treatments, while the treatments with full recommended rate of mineral fertilizer alone or in combination with 10t/ha foliage of jatropha stood out to be superior than all other treatments. This implies that higher supply of nutrients significantly enhanced the N-uptake of pearl millet in the study area. Divya et al. (2017) indicated that an increase in uptake of nutrients empowers plants to build more photosynthates that results in greater stover yield

Table 5: Effect of treatments on stover nutrients (N.P.K) uptake (kg/ha)

No.	Treatment description	N	P	K
1.	Absolute control	19.44e	11.52cd	34.06de
2.	Half recommended mineral fertilizer	42.73c	22.72ab	36.89cde
3.	Full recommended mineral fertilizer	84.63a	25.55a	56.09ab
4.	5t/ha foliage of jatropha only	26.81d	08.90d	30.0e
5.	5t/ha foliage plus half mineral fertilizer	47.37bc	15.44cd	34.47de
6.	5t/ha foliage plus full mineral fertilizer	51.37b	20.53ab	43.96bcd
7.	10t/ha foliage of jatropha only	41.31c	13.22cd	32.65de
8.	10t/ha foliage plus half mineral fertilizer	50.49b	17.77bc	49.17abc
9.	10t/ha foliage plus full mineral fertilizer	82.17a	27.06a	60.78a
	C.V.(%)	10.6	9.5	7.4
	SE	5.0	1.7	3.1

In each column, means carrying the same letters are not significantly different according to DMRT at 5% LOS.

Furthermore, Hussain et al. (2008) reported that nutrients uptake and distribution to various plant parts vary mostly with the fertility of soil, application of mineral fertilizer, growth stage of the plant as well as environmental conditions; while N-fertilization increases the concentration of N, P and K in plants.

All treatments having a combination of mineral fertilizer and jatropha foliage significantly performed better in N-uptake than treatments having foliage of jatropha alone.

P-uptake was also significantly highest in treatments with full rate of mineral fertilizer alone or in combination with foliage of jatropha. However, P-uptake in treatments with foliage of jatropha alone was statistically at par with control treatment. This means that application of foliage alone did not improve P-uptake in pearl millet production. Mason et al. (2015) concluded that phosphorus is the most limiting nutrient in pearl millet production, therefore when using foliage of jatropha, it is pertinent to supply judicious amount of phosphorus as well. The result showed the relevance of using half recommended rate of mineral fertilizer in combination with 10t/ha foliage of jatropha for the production of pearl millet.

With respect to K-uptake, the result revealed that treatments having 10t/ha jatropha foliage combined with either full or half recommended rate of mineral fertilizer were superior than other treatments. This further emphasizes the benefit of applying lower rates of mineral fertilizer in combination with about 10t/ha foliage of jatropha to boost pearl millet productivity. Chandrasekaran et al. (2010) described potassium as the nutrient that regulates the uptake of water, N and P by plant roots and activates the functions of many plant enzymes, thereby making plants more tolerant to diseases, cold and drought.

Conclusion

In the low fertility soils of Nigerian Sudan savanna where poor resource farmers cultivate crops on marginal lands, the use of jatropha foliage (a cheap and accessible organic input) as soil amendment for pearl millet production increased grain yield by at least 68-85% (using 5t/ha and 10t/ha application rates respectively). The amendment alone, did not attain optimum grain and stover yield levels. However, the complementary use of 10t/ha foliage of jatropha plus half recommended rate of mineral fertilizer achieved optimum grain yield of pearl millet as well as higher yield of stover. Nutrient uptake was also improved by the application of the foliage, especially in combination with lower rates of mineral fertilizer. It is therefore recommended that farmers can establish jatropha curcas plants around their fields in order to use the foliage along with lower rates of mineral fertilizer to improve the productivity of pearl millet, which is an important crop in the arid and semi-arid areas of Africa and Asia and consumed by over 100 million people as staple food.

References

1. Adamty, N. (2016). Challenges for Organic Agriculture Research in Tropical Zones. Soil Fertility and Waste Management in The Tropics. BIOFAC, Nurnberg, Germany.

2. Anderson, J.M. and J.S.I. Ingram (1993). Tropical Soil Biology and Fertility. A handbook of methods 2nd edition. CAB International. Wallingford, U.K.

3. Bender, R., Haegele, J.W., Ruffe, M.L. and Below, F.E. (2013). Modern corn Hybrids' Nutrient Uptake patterns. Better crops vol. 97 No. 1.

4. Bhuva, H.M., Detroja, A.C. and Khanpara, M.D. (2018). Requirement of Nutrients for Pearl Millet Production under Saurashtra conditions. Int'l. Journal of Envtal. Sci. & Natural Resources. Vol. 9, issue 4.

5. Brady, N.C. and Weil, R.R. (2008). The Nature and Properties of Soils. Pearson/ Prentice Hall Limited, New Jersey.

6. Bray, R.H. and Kurtz, L.T. (1945). Determination of Total Organic and Available forms of Phosphorus in Soils. Soil Sci. 19:39 – 45.

7. Bremner, J.M. (1965). Regular Microkjeldahd Method for Determination of Total Soil N. in Methods of Soil Analysis. C.A. Black (ed). Part 2. Am. Soc. Agron. No. 9. Madison. Wis. Pp. 1149 – 1176.

8. Chandrasekaran, B., Annadurai, K and E. Somasudaram (2010). A Textbook of Agronomy. New Age International (P) limited Publishers, New Delhi.

9. Cheng, Z. and L. Catherine (2016). Estimating house hold demand for Millet and Sorghum in Niger and Nigeria. Socioeconomics discussion paper series no.39 ICRISAT, Mali.

10. Divya, G., Vani, K.P., Badu, P.S. and K.B.S. Devi (2017). Yield attributes and Yield of summer pearl millet as influenced by cultivars and integrated nutrient management. Int'l. Journal of current microbiology and applied sciences. Vol. 6. No. 10: 1491-1495.

11. FAO (2017). Food and Agricultural Organisation of United Nations Statistics Division. Data-Crops Production. www.fao.org/faostat/en

12. Foth, H.D. (1990). Fundamental of Soil Science (8th edition). John Wiley and Sons. New York.

13. Gill, H. (2018). Call for action: FAO places nutrient-rich millets center stage to boost global innovation. News and Analysis on the Bakery and Snack Industries. Bakeryandsnack.com

14. Giller, K.E. (2001). Nitrogen Fixation in Tropical Cropping System. Second Edition. CAB International, Wallingford, U.K.

15. Hans, D. (2018). Proposal for international year of millets. Plant Production and Protection Division. FAO, Rome.

16. Horneck, D.A., Sullivan, D.M., Owen, J.S and Hart, J.M. (2011). Soil test interpretation guide. Oregon State University Extension Services. http://extension.oregonstate.edu

17. Hussain, M.A., Ogunlela, V.B., Ramalan, A.A. and Falaki, A.M. (2008). Mineral Composition of Dry Season Maize in Response to Varying levels of Nitrogen, Phosphorus and Irrigation at Kadawa, Nigeria. World Journal of Agric. Sciences. 4(6): 775-780.

18. ICRISAT (1997). International Crop Research Institute for the Semi-Arid Tropics. Report, 1996.

19. Jones, D.L., Paul, C. and Withers, P.J A. (2013). Nutrient stripping: The global disparity between food security and soil nutrient stocks. Journal of Applied Ecology.50, 851-862.

20. Kalra, Y.P. and D.G. Maynard (1994). Methods Manual for forest soil and plant analysis. Information Report NOR-X-319. Canadian forest service. Edmonton, Alberta T6H 3S5.

21. Maman, N. and S.C. Mason (2013). Poultry manure and inorganic fertilizer to improve pearl millet yield in Niger. African Journal of Plant sci. 7:162-9.

22. Manjeet, J. and Kumar, P. (2017). Influence of manure and nitrogen levels on nutrient uptake, soil fertility and economics of pearl millet under Semi-Arid environment. Forage research 43 (3):208-212

23. Marschner, P. (2012). Marschner's Mineral Nutrition of Higher Plants (3rd edition). Academic Press, London.

24. Maryam, A.D., Ignatius, I.A., Tangoona,B.P., Ofori, K., John, S.Y. and B.E. Ifie (2017). Farmers production constraints, knowledge of striga and preferred traits of pearl millet in Jigawa state of Nigeria. Global journal of scientific frontier research. Vol. 17 issue 3 version 1.

25. Mason, S.C., Maman, N and S. Pale (2015). Pearl Millet production practices in semi-arid West Africa: A review. Exptal. Agric. 1(4):1-21.

26. Nelson, D.W. and Sommers, L.E. (1982). Total Carbon, Organic Carbon and Organic Matter in Page, A.L., R.H., Miller and D.R. Keeney (eds.) Methods of Soil Analysis Part 2. American Society of Agronomy, Madison. Pp. 53 – 579.

27. Miller (2016). World Millet and Sorghum market. Parentez media. info@millermagazine.com

28. Okelabo, J.R., Gathua, K.W. and Woomer, P.L. (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. Nairobi, Kenya.

29. Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G. and Gillar, K.E. (2001). Organic Inputs for Soil fertility Management: Some Rules and Tools. Agriculture, Ecosystem and Environment 83:27 – 42.

30. Macauley, H. and Ramadjita, T. (2015). Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat. In UNECF (Ed). Feeding Africa. Pp36. Abdou Diouf Int'l. conference centre.

31. Reddy, B.P.S., Madhuri, K.V., Venkaiah, K. and Prathima, T. (2016). Effect of Nitrogen and Potassium on Yield and Quality of Pearl Millet (Pennisetum glaucum L.). Int'l. Journal of Agric. Innovation and Research. 4(4): 2319.

32. Sanginga, N. and Woomer, P.L. (2009). Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process. TSBF – CIAT. Nairobi.

33. SAS (2013). Statistical Analysis System 9.4. SAS Institute, Inc. Cary, N.C, U.S.A.

34. Scholl, L.V. and Nieuwenhuis, R. (2007). Soil Fertility Management. Digigrafi, Agromisa. Wageningen, Netherlands.

35. Senthilkumar, N., Poonkodi, P. and Prabhu, N. (2018). Response of pearl millet to integrated use of organics and fertilizer. Journal of Ecobiotechnology 10: 01-04. Doi: 10.25081/jebt 2018. V10. 3510.

36. Soil Survey Staff (1975). Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. Handbook No. 436.

37. Tarfa, B.D., Uyoubisere, E.O., Chude, V.O., Raji, B.A. and Yaro, D.T. (2001). Effect of complementary use of Foliage of A. indica, P. biglobosa and N.P.K. on yield and Nutrient Uptake of Maize in a Savanna Soil. Nig. J. of Soil Res. 2:43 – 50.

38. Tisdale, S.L., Nelson, W.L., Beaton, J.O. and Havlin, J.L. (2003). Soil Fertility and Fertilizers. Prentice Hall of India, New Delhi.

39. Traore, M; Bismarck, H; Tabo, R; Nikiema, A. and Ousmane, H. (2012). Potential for Agronomic enhancement of millet yield via Jatropha curcas oil cake fertilizer amendment using placed application technique. Int'l. J. Biochem. Sci. 6(2).808-819.

40. Vanlauwe, B; Bationo, A; Chianu, J; Giller, K.E; Merckx, R; Mokwunye, B; Ohiokpehai, O; Pypers, P; Tabo, R; Shepherd, K; Smaling, E.M.A. and Woomer, P.L. (2010). Integrated Soil Fertility Management: Operational Definations and Consequences for Implementation and Dissemination. Outlook Agric. 39, 17-24.

41. Victor, M.R., Marco, L., Aurelie, G., Federico, A.G. and Dendooven, L. (2010). Greenhouse Gas Emissions and C and N Mineralization in Soils of Chiapas (Mexico) Amended with Leaves of Jatropha curcas L. Applied Soil Ecology 46(2010) 17 – 25.