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Research Article

Soil Properties, Grain Yield of Soybean (*Glycine max*) as Affected by Different Nodumax Stickers Grown on an Ultisol in Derived Savannah Ecology of Ishiagu Southeast Nigeria

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Abstract

A trial on soil properties, grain yield of soybean (*Glycine max*) as affected by different nodumax stickers was conducted in derived savannah ecology of Ishiagu southeast Nigeria. In the experiment, a randomized complete block design (RCBD) was used with six (6) treatment replicated three (3) times, namely gum arabic, liquid milk, vegetable oil, no sticker, water and Control (No Inoculation). Pre-planting physico-chemical properties of the soils were determined to know the soil status, while inoculation was done in the field before planting. Soil properties such as pH, cation exchange capacity, organic carbon, available phosphorous, bulk density, particle size and porosity were evaluated. Also anaylsed were the yield components which included number of pods, number of seeds per pod, 100 seed weight and grain yield. After the data analysis which was drawn at 5% level of probability, the results revealed that the soil chemical properties analysed were significantly ($P < 0.05$) affected the treaments while the soil physical properties were not. Results also revealed higher yield values in inoculated plots. The values recorded in plots which had gum arabic as sticker were highest, though statistically similar to those with milk as sticker. Gum arabic, therefore, can therefore be substituted with milk when gum arabic is not available.

Keywords: Nodumax; Inoculant; Stickers; Soybean; Soil Properties; Yield

Introduction

The adverse effects of synthetic inputs in conventional agriculture practices have led to an increased call for organic agricultural practices. According to [1], though the culture of using chemical fertilizers and pesticides increases crop yield, it accelerates soil acidification and poses the risk of contaminating ground water and the atmosphere. In this regard, attempts have recently been made towards the production of nutrient rich high quality fertilizer (biofertilizer) to ensure bio-safety [2]. Biofertilizer should not be confused with organic fertilizers, as they are preparations containing living cells or latent cells of efficient strains of microorganisms, they help crop plants' uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil [3]. Biofertilizer are applied through inoculation, which is the process of attaching the bacteria to the seed or soil before planting, a process which aims at ensuring that adequate number of bacteria needed for a successful establishment of the crop is avaliable [4]. Nodumax (which contains *Rhizobium*) is a type of biofertilizer developed at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. It enhance the yield of legume crops thereby reducing the use of nitrogen fertilizer in legume crops production and comes with a sticker called gum arabic [5]. Soybean (*Glycine max*) a legume in the family *Fabaceae*, It is an important food and oilseed crop and contributes to soil fertility through N_2-fixation [6]. When soybean roots are infected by the right *Rhizobium* by inoculation, nodules are generally formed and have high prospect for N_2 - fixation [6]. Sticking the inoculant with the seeds or soil during the application process enhances affects the efficacy of the inoculants [5]. Some additional sticker materials that have been identified include carboxymethyl cellulose, sugar solution, corn syrup, honey, powdered milk, evaporated milk, mineral oil, or a vegetable oil such as peanut oil or soybean oil. The main drawback in the use of gum Arabic as sticker it easily gets hardened, making usage difficult. When farmers cannot overcome these problems, they see no need for inoculation, thus reducing their adoption of the technology, making both the manufacturers and the users the losers. According to [5], the most excellent sticker for nodumax application is yet to be determined. The objective of this workis therefore to determine the most effective readily available sticker that can be used in place of gum arabic; that will help inoculant stick well, thereby encouraging fixation and at long run enhancing soil conditions and yield of crop.

Materials and Method

Location of experimental site

The experiment was conducted at the Research and Teaching Farm of the Federal College of Agriculture, Ishiagu, South-eastern Nigeria. The area lies between latitude 5º 55´ N and 6º 00´ N, and longitudes 7º 30´ E and 7º 35´ E in the derived savannah agro-ecology. The mean annual rainfall of the area is 1350 mm, spread from April to October with average air temperature of 29ºC [7].

Experimental design and layout

The field was cleared, prepared manually into eighteen beds measuring 2m x 2m which represent the plot size. The treatments were arranged in a randomized complete block design (RCBD) with six (6) treatment replicated three (3) times, namely Gum Arabic, Liquid milk, vegetable oil, no sticker, Water and, Control (No Inoculation). The *Rhizobium* inoculant (NODUMAX) and the TGX 1 448-2E variety of soybean seeds were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan in Nigeria. Gum Arabic, one of the stickers used, was enclosed in the Nodumax pack, while the other stickers such as milk, vegetable oil, liquid milk and water were obtained from the open market in Ishiagu. The inoculation was done in the field just before planting using the Slurry method outlined by(8). 5 grams of the inoculant was sprayed on the seeds after the seed have been covered by each the stickers. The inoculated seeds were put in a container covered with cloth to protect it from direct sunlight. Two seeds were planted per hole at a depth of 4 cm and planting distance of 50cm by 50cm. The seedlings were later thinned down to one seedlings per hole at 2 weeks after sowing (WAS). Before sowing, a basal application of phosphorus fertilizer (P_2O_5) at 30kg/ha was done. Weeding was done manually by hand using a hoe at 3 and 6 WAS.

Prior and after planting a composite soil sample were collected from the experimental site, from each of the plots to determine the changes that occurred due to treatments applications. The soil pH was measured according to [9]. Organic carbon was determined as modified by [10]. Total nitrogen was determined by semi-microkjedahl digestion method [11]. Cation Exchange was determined by titration method [12]. Exchangeable Base sodium (Na) and potassium (K) were determined from ammonium acetate leachate using auto electric flame photometer. The quantity of available Phosphorus was determined by the Bray II method [13]. Calcium (Ca) and magnesium (Mg) was determined using the complex titration method, while Exchange Acidity (EA) was determined by titration method using 1.0 NaCl extract [9]. Bulk density (BD): Core samples were allowed to drain freely for 24 hours before being oven dried for determination of bulk density. Total Porosity: Total porosity (Tp) was obtained from bulk density (ρb) values together particle density (ρs) of 2.65 Mg/m^3 as follows; Porosity = Tp = 100(1 – ρb/ρs). Saturated hydraulic conductivity (Ksat): The saturated hydraulic conductivity was calculated [14]. Particle size distribution of the samples was determined by the hydrometer method.

Data collection on plant parameters

Number of Pods per Plant, Number of Seeds per Pod, 100-Seed Weight and grain yield were determined at harvest.

Data analysis

Data collected were analyzed using analysis of variance (ANOVA) and significant treatment means were separated using least significant difference. (F-LSD) and all inference made at 5% level of probability levels according to [15].

Results and Discussion

Soil properties

Pre-planting Physico-chemical Properties of the Soil

The pH measured in water was 5.2 and the value of 10.60 cmol/kg was recorded for cation exchange capacity (Table 1). The analysis also indicated that the exchangeable sodium, potassium, calcium and magnesium were; 0.11 cmol/kg, 0.17 cmol/kg, 3.37 cmol/kg and 2.40 cmol/kg, respectively. In addition, the exchangeable acidity and available phosphorous in the studied soil had values as 1.10 cmol/kg and 4.31 mg/kg, respectively. Table 1. The soils were sandy loam with 12% clay, 20% silt and 68% sand contents. The bulk density was 1.39 mg/m^3, soil porosity 47.57%, saturated hydraulic conductivity 0.36 cm/h and particle size 2.56 mg/m^3. Soil organic carbon concentration recorded 6.47 g/kg, whereas the total soil nitrogen was 1.35 g/kg.

Effect of diferent stickers on the soil properties

The soil pH was significantly ($P \leq 0.05$) affected by treatments, the value of 4.9 obtained from both gum rrabic and milk as sticker was lower than the value of 5.5 recorded in control (Table 2). There was significant ($P > 0.05$) difference on total nitrogen value, plots inoculated with gum arabic as sticker gave the highest value of 2.25 (gkg^{-1}) while control plot had lowest values of 1.55 (gkg^{-1}). The organic cabon content was significantly ($P \leq 0.05$) affected by treatments, the values of 8.20 gk/g values obtained from gum arabic sticker differed from the values obtained from all other stickers.

Soil properties	Value
Clay (%)	12
Silt (%)	20
Sand (%)	68
Textural class	Sandy loam
Bulk density (mg/m^3)	1.39
Porosity (%)	47.57
Saturated hydraulic conductivity (cm/h)	0.36
Particle size (mg/m^3)	2.56
pH (H_2O)	5.2
Organic Carbon	6.47
Total nitrogen (gkg^{-1})	1.35
Exchangeable bases	
Sodium (Na^+) (cmol/kg)	0.11
Potassium (K^+) (cmol/kg)	0.17
Calcium (Ca^{2+}) (cmol/kg)	3.37
Magnesium (Mg^{2+}) (cmol/kg)	2.40
Cation exchange capacity (cmol/kg)	10.10
Exchangeable acidity (cmol/kg)	1.10
Available phosphorous (mg/kg)	4.31

Table 1: Initial physical and chemical properties of the studied soil (0-20cm) depth.

The cation exchange capacity value of 1.44 cmol/kg gotten from gum arabic significantly ($P \leq 0.05$) differed from control (Table 2). Soil samples collected from plots with gum arabic had the highest avalible phosphorous of value 11.93 mg/kg though was statistically similar to other stickers but significantly differed from control with (10.11 mg/kg) (Table 2). The bulk density and total porosity of the studied soil was not significantly ($P > 0.05$) affected by the stickers.The same trend was observed both in the particle size and saturated hydraulic conductivity inoculation where the use different stickers did not have any significant ($P > 0.05$) effect on values obtained (Table 3).

Effect of diferent stickers on the grian yield components

The number of pods per plant significantly ($P \leq 0.05$) differed among treatments, milk recorded 61 pods higher than 42 and 38 pods gotten in water and control respectively and but similar to the other stickers (Table 4). Result also shows no significant effect on the number of seed per pod and the 100 seed weight. On the seed yield kg/ha, Gum Arabic recorded a value of 1,390.15kg/ha, statistically similar to milk which obtained 1,384.64kg/ha but significantly ($P \leq 0.05$) higher than other stickers (Table 4).

Treatment	pH (water)	Total Nitrogen (gkg^{-1})	Organic carbon (gkg^{-1})	Cation exchange capacity (cmol/kg)	Exchangeable Acidity (cmol/kg)	Available phosphorus (mg/kg)
Gum Arabic	4.9	2.25	8.20	12.65	1.44	11.93
Milk	4.9	2.20	7.84	12.71	1.42	11.12
Vegetable oil	5.2	1.94	7.80	10.03	1.40	11.32
Honey	5.2	1.93	7.80	10.15	1.41	11.31
Water	5.2	1.70	7.79	10.13	1.47	11.22
Control	5.5	1.55	6.25	10.11	1.29	10.11
$LSD_{0.05}$	0.17	0.08	0.24	1.29	0.10	0.51

Table 2: Effect of diferent stickers on chemical soil properties.

Treatment	Bulk density (mg/m^3)	Porosity (%)	Particle size (mg/m^3)	Saturated hydraulic conductivity (cm/h)
Gum Arabic	1.29	48.01	2.56	0.36
Milk	1.29	47.87	2.54	0.37
Vegetable oil	1.30	47.84	2.54	0.35
Honey	1.31	48.23	2.57	0.35
Water	1.30	49.24	2.56	0.36
Control	1.30	47.56	2.55	0.37
$LSD_{0.05}$	NS	NS	NS	NS

Table 3: Effect of diferent stickers on physical soil properties.

Treatment	Number of Pods/Plant	Number of seeds/Pod	100 Seed weight(g)	Seed yield kg/ha
Gum Arabic	60	2	12.87	1390.15
Milk	61	2	12.84	1384.64
Vegetable oil	57	2	12.83	1322.37
Honey	57	2	12.57	1325.42
Water	42	2	12.80	1054.04
Control	38	2	12.63	1019.51
$LSD_{0.05}$	5.68	NS	NS	6.51

Table 4: Effect of diferent stickers on yield components.

Discussion

The lower pH value observed in the inoculated plots might be due to liberation of organic acids contained in the inoculants. This observation is in agreement with [16] who reported that the application of biofertilizer can alter the soil pH evidenced by reducing the alkalinity slightly from 8.5 to 7.8. The higher values of soil total nitrogen, phosphorous and organic carbon recorded in the inoculated plots particularly those with gum Arabic as sticker could be attributed to the fact that gum arabic is more tenacious and gives the best adhesion more than other stickers, this promotes increasesd root hair infection of the *Rhizobia,* thus increasing organic activities which led to N_2- fixation and nutrient availability. This also agreed with [17] who reported that biofertilizers generate plant nutrients like nitrogen and phosphorous through their activities in the soil or rhizosphere and make them available to the plants on the soil. The higher values of cation exchange capacity and exchangeable acidity in the treated plots might be attributed to the humic and fulvic acid content that enhance microbial activity and increased nitrification. This is in comformity with [18] who reported an increase in soil exchangeable acidity in legumes as result of increased N_2- fixation. The soil physical properties were not affected by stickers. This is in agreement with the findings of [19] who found out that inoculation of crops does not significantly affect the soil physical properties.

There was increase in crop yield parameters in the inoculated plots when compared to the non inoculated ones. [20,21] all reported that inoculation by *Rhizobial* bacteria brought about increase in the number of pods per plant, number of seeds per pod, thousand grain weights and the grain yield of soybean. On the contrary [22,23] observed lack response on yield improvement by inoculation. In most of the growth and yield parameters in the present study studied, Gum Arabic proved to be the best sticker it as recorded overall highest values although together with milk. The effectiveness of Gum Arabic and milk could be attributed to their high adhesive property [24]. reported that Gum Arabic is more tenacious and provides good adhesion. This implies that materials that leave a sticky coating on the seed surface are better.

Conclusion

The use of gum arabic and milk as stickers proved to be effective in improving the soil chemical properties and yield of crop. Gum arabic can therefore be substituted with milk, especially where gum ararbic is not readily available.

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