Journal of Agriculture and Food Sciences **Ogbuehi H.C.**
Volume 18, Number 2, October 2020, pp 54 - 72 .

EFFECT OF NODUMAX INOCULANT ON MORPHO-PHYSIOLOGICAL PARAMETERS, NUTRIENT CONTENT AND YIELD OF SOYBEAN (GLYCINE MAX.L)

OGBUEHI H.C.

Department of Crop Science and Biotechnology, Faculty of Agriculture and Veterinery Medicine, Imo State University, P.M.B 2000, Owerri, Email:ogbu_h@yahoo.com

ABSTRACT

The field study was carried out at the Teaching and Research Farm of Faculty of Agriculture and Veterinary Medicine of Imo State University, Owerri, to investigate the effect of Nodumax inoculants on Morpho-Pysiological parameters, Nutrient content and yield of Soybean (Glycine max). The experimental design was Randomized Complete Block Design with five treatments and four replications. Treatments consist of Gum Arabic Slurry, Honey Slurry, Powdered milk Slurry, Sugar Slurry (as adhesive agents) and control. The results obtained indicated that Nodumax inoculation, with adhesive agents especially Gum Arabic improved the Morpho-Physiological parameters such as plant heights, leaf area, leaf area index, leaf area ratio, Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) and shoot dry weight compare to the control. Inoculation increased soybean grain yield across the various adhesive agents ranging from 909.45kg/ha for non-inoculated control to 1002.99kg/ha for inoculated using Gum Arabic, as sticker agent. Proximate composition of inoculated seeds was significantly (P<0.05) improved compare to the control. However, it was observed that Nodumax inoculation correspond to increase in soybean growth characteristics which subsequently increased the yield and improved the nutritional status of soybean. This study has shown that the type of adhesive for coating of seed during rhizobium inoculation could impact positive change in growth parameters, Nutritional status and yield of soybean.

Key words; Adhesive, Nodumax, Inoculant, Growth parameters, Soybean

https://dx.doi.org/10.4314/jafs.v18i2.4

INTRODUCTION

Soybean *(Glycine max (L.)* Merrill*)* is a special of dietary protein whose production is gaining prominence in semi-arid regions of Sub-Sahara Africa. However, yields are drastically low due to poor soil fertility, lack of improved cultivars, poor management practices and unavailability of inputs.

The rhizosphere is the soil region where activities mediated by micro-organisms are specifically influenced by the root systems. This area includes the soil connected to the plant roots and often extends a few millimeters off the root surface, being an important environment for the plant and microorganism interactions (Lynch, 1990; Gray and Smith, 2005), because plant roots release a wide range of compounds involved in attracting organisms which may be beneficial, neutral or detrimental to plants (Lynch, 1990; Badri and Vivanco, 2009).

Interactions between plants and bacteria occur through symbiotic, endophytic or associative processes with distinct degrees of proximity with the roots and surrounding soil. Endophytic PGPB are good innoculant candidates, because they colonize roots and create a favorable environment for development and function. Non-symbiotic endophytic relationships occur within the intercellular spaces of plant tissues, which contain high levels of carbohydrates, amino acids, and inorganic nutrients (Bacon and Hinton,2006)

The soybean (*Glycine max*), is an annual summer legume native of South-eastern Asia, which is used as human food (Liu, 1999) and livestock feed as well as for several industrial purposes (Ali, 2010). Currently, this legume is one of the main crops cultivated for oil extraction (35.9 million tons oil and 57% global oilseed production), preceded only by the palm oil (FAO, 2011).

The success and efficiency of PGPB as inoculants for agricultural crops are influenced by various factors, among which the ability of these bacteria to colonize plant roots, the exudation by plant roots and the soil health. The root colonization efficiency of PGPB is closely associated with microbial competition and survival in the soil, as well as with the modulation of the expression of several genes and cell-cell communication via quorum sensing (Danhorn and Fuqua, 2007; Meneses *etal*., 2011;Alquares *etal*.,2013; Beauregard *et al*., 2013).

Plant roots react to different environmental conditions through the secretion of a wide range of compounds which interfere with the plant-bacteria interaction, being considered as an important factor in the efficiency of the inoculants (Bais *et al*., 2006; Cai *et al*., 2009, 2012). Agricultural production currently depends on the large-scale use of chemical fertilizers (Adesemoye *et al*., 2009). These fertilizers have become essential components of modern agriculture because they provide essential plant nutrients such as nitrogen, phosphorus and potassium. However, the overuse of fertilizers can cause unanticipated environmental impacts (Adesemoye *et al*., 2009).

To achieve maximum benefits in terms of fertilizer savings and better growth, the PGPB-based inoculation technology should be utilized. Moreover, the use of efficient inoculants can be considered an important strategy for sustainable management and for reducing environmental problems by decreasing the use of chemical fertilizers (Alves *et al*., 2004; Adesemoye *et al*., 2009; Hungria *et al*., 2005).

Nodumax is a new legume inoculation technology developed at the IITA Business Incubation Platform that boosts the yield of Soybean by 30 -40%.it also serves to replace nitrogen (IITA,2015).Nodumax is a biofertlizer, it contains 50% of culture (rhizobia) and 50% peat based carrier containing elite *Bradyrhizobi*a.it is packaged in 100g quantities intended for 10 to 20 kg of soybean seed along with gum Arabic for distribution to agro dealers and soybean production associations in Nigeria (IITA,2015).Nodumax is made to solve the issue of low crop prudctuvity of most legume crops such as Beans and Soybeans

Main objective of this study is to evaluate the use of nodumaxinnoculant on Morph-physiological paramters, yield and Proximate composition of Soybean.

MATERIALS AND METHODS

Study Location

The experiment was conducted at the Teaching and research Farm of Faculty of Agriculture and Veterinary Medicine, Imo State University, Owerri. Owerri lies between latitudes $5^{o}20'$N and 6^{o} $55'$ E, and longitudes $6^{o}35'$E and 7^{o} $08'$E on elevation of 71m above the sea level, within the South East Rain Forest Agricultural Zone of Nigeria. The area as reported by NIMET (2012) maintains an average annual rainfall of 2,500mm, 27^{0}C temperature and Relative humidity of 85%.

Experimental Materials.

Seeds of soybean (TGX 1951-3f) and nodumax inoculants were procured from IITA Ibadan, Oyo State. Sugar, honey powdered milk were purchased from Ekeonunwa market in Owerri.

Stickers as Treatments

Sugar Slurry (10% in water), honey slurry (10% in water) and powdered milk Slurry (10% in water), to achieve the above treatment options, Mix 10 g of each of the stickers in 100 ml of cold water. Stir until they are dissolved. The rate of sticker solution mixed with the inoculants depends on the type of seed used. Smaller seeds require more sticker solution per seed weight than larger seeds because they have a larger surface area to be coated.

Experiment Design and Layout

The experiment was laid out in Randomized Block Complete Design (RBCD) with four replicates. 10% sugar, 10% of honey, 10% gumarabic and powdered milk formed the treatment and it was replicated four times.

Planting and Agronomic operations

Soil samples were collected randomly at 0-15cm depth from different beds in the site and bulked together for physico-chemical analysis. Soybean seeds were planted at a depth of 2-3cm in the 1mx1m beds with two seeds per hole at a planting distance of 50 x 50cm. Thinning was done at 14 days after planting to reduce the plant stand to one per hole. Weeding was done by hand picking throughout the period of research to keep the beds weed free.

Data Collection

The following parameters were collected:

1) **Emergence Percentage:** This was calculated 5 daysafter planting. It was calculated using the formularbelow:

$$\frac{\text{No of seeds emerged}}{\text{No of seeds sowed}} \times \frac{100}{1}$$

2) **Plant Height:** This is the distance from the ground level of the plant to the Apex of the plant. It was measured using ruler (graduated in centimeter).

3) **Leaf Area per Plant (cm^2):** This was calculated using the formular: 6.532 + 2.045 (Li Wi) were Li = maximum lengths of terminal leaflet of the leaf.

Wi = maximum width of terminal leaflet of the leaf.

According to Ogoke*et al.* (2003).

4) **Leaf Area Ratio(cm^2g^{-1}):** This was calculated using the formular:

$$\frac{\text{Total leaf area}}{\text{Total dry weight of the plant,}}$$

as described by Kang and Van (2004).

5) **Leaf Area Index Per Plant:** This was obtained by a simple formular, leaf area index per plant

$$= \frac{\text{Leaf Area per plant}}{\text{Area covered by the leaf}}$$

6) **Relative Growth Rate ($gg^{-1}wk^{-1}$):** is the growth rate relative to the size of the population. It is also called the exponential growth rate or the continuous growth rate.

It was calculated using the formular as described by Akonye and Nwauzoma, (2003)

$$RGR = 2.303 \frac{\text{Log}(W_2 - W_1)}{T_2 - T_1} \quad \text{or} \quad \frac{\text{Log } W_2 - \log W_1}{T_2 - T_1}$$

W_1 = initial weight

W_2 =subsequent weight

T_2 = subsequent time

T_1 = initial time

7) **Net Assimilation Rate (NAR)(gcm^2wk^{-1}):**

$$NAR = 2.303 \text{ Log}(L_2 - L_1) \frac{x}{T_2 - T_1} \frac{W_2 - W_1}{L_2 - L_1}$$

Where,

W_1 – initial weight

Journal of Agriculture and Food Sciences **Ogbuehi H.C.**
Volume 18, Number 2, October 2020, pp 54 - 72 .

W_2 – subsequent weight

L_1 – initial leaf area

L_2 – subsequent leaf area

T_1 – initial time

T_2 – subsequent time

8) **Shoot Dry Weight:** It was obtained when the shoot has been dried up with weighing balance after at 80°C for 24hours.

9) **Number of pods:** This was obtained by visual counting of pods per plot.

10) **100 seed weight:** This was calculated using 100 dried seeds of soybean.

11) **Yield:** This was calculated with the formular;

$$\frac{\text{Seed weight (Kg)}}{\text{Land area (m}^2} \times \frac{10,000}{}$$

RESULTS

Effect of Treatment on the Percentage of Emergence

Table 1 showed the effect of Nodumax inoculant on the percentage emergence. Treatments (sugar sticker slurry) recorded higher percentage emergence (82.82) which was not significantly difference ($P<0.05$) from the control and other treated plots. The lowest percentage emergence (54.64) was recorded from T_4 (milk slurry sticker) which was not significantly different ($P<0.05$) from the other treated plots and control as shown in Table I.

Effect of Treatment on Mean Plant Height

Plant height was significantly affected by treatment at early stage and maturity stage compared to the control. Control was found to perform better than all the treated plots at 2WAP: At 4WAP T_5 (sugar slurry sticker) recorded the highest plant height (25.825cm) which was not significantly different from the control (21.500). The lowest plant height (20.350cm) was recorded from T_4 which was not significantly different ($P<0.05$) from control and other treated plots, at 6 WAP T_4 (milk slurry sticker) recorded the highest plant height (37.350cm) which was significant different from control which recorded the lowest mean plant height (24.050cm). Also T_5 (sugar slurry sticker) recorded mean height of 34.150cm which was significantly different from control but not significantly different from T_3 (31.475cm) and T_2 (30.00cm).

At 8WAP T_5 recorded highest mean plant height (46.675cm) which was not significantly different from the lowest (36.125cm) recorded from control. This was followed by T_4, (38.200cm) and T_3 (37.750cm) respectively relative to control which did not show any significant different (P<0.05). At 10WAP T_5 recorded the highest plant height of 57.85cm which was significantly different from lowest (47.350cm) recorded from control. Also treatments (honey slurry sticker) recorded plant height (52.500 cm) which was higher than T_4 (48.175cm) and T_2 with plant height (48.575cm) which were not significantly to each other as shown in Table 2.

However, the used of sticker materials influence inoculation of Nodumax on the seed of soybeans which enhances the plant height compare to the control.

Effect of Treatment on Leaf Area (Cm^2) of Soybean

Table 3 showed that there was no significant effect of treatment on leaf area of soybean. At 2WAP, Treatment 3 recorded the highest leaf area (183.63cm^2) respectively which was not significantly different (P<0.05) from the lowest leaf area (132.77cm^2) recorded from control whereas at 4WAP T_3 recorded the highest leaf area (347.74 cm^2) which was significantly different (P<0.05) from control (130.74 cm^2). At 6WAP T_5recorded the highest mean leaf area of 289.16cm^2 which was not significantly different from lowest (209.67cm^2) recorded from Treatment$_2$ and control (209.32cm^2). T_4 recorded a higher leaf area (281.1cm^2) than T_3 (250.21cm^2) and T_2 (202.6.7cm^2) respectively.

At 8WAP, T_5 recorded the higher leaf area (709.7cm^2) which was not significantly different (P<0.05) from the lowest leaf area (303.1cm^2) recorded from control. This was followed by leaf area (705.7cm^2) which was not significantly different from T_2 and T_3 respectively. (table3). At 10WAP T_5 recorded the highest leaf area (817.0cm^2) which was not significantly different (P<0.05) from lowest (635.8cm^2) recorded from control. The leaf area (746.8cm^2) recorded from T_2 was higher than those 8WAP T_4 (746.5cm^2) and T_3 (737.96cm^2) respectively. There was no significant increase in the leaf from 6WAP to 10WAP in all treatments.

Effect of Treatment on Leaf Area Index (LAI) of Soybean

The result of leaf area index analysis as shown in table 4, revealed no significant different (P<0.05) among treatments except only at 8WAP.

However, at 2 and 4WAP T_5 recorded the lowest leaf area index (1.0220 and 0.8433 respectively) which was not significantly different from the highest (1.6840 and 1.393) recorded from T_1 and T_3 treated plots respectively. Also, at 6WAP T_3 recorded the highest leaf area index of 0.8918 which was not significantly different from the lowest recorded from T_5 (0.5775). Similarly, at 8 and 10WAP T_3 consistently recorded the highest leaf area index (0.6375 and 0.6275, respectively) which was significant only at 8WAP compared to the lowest (0.2430 and 0.3348) recorded from control as shown in table 4.

Effect of Treatment on Leaf Area Ratio of Soybean

The leaf area ratio was not significantly influence by treatment throughout the period of this experiment as shown in Table 5; at 2WAP, T_2 recorded the higher leaf area ratio (351.75) which was not significantly different from the lowest (271.67) from T_4. However, control (T_1) recorded higher leaf area ratio (299.12) which was not significantly different from those recorded from T_5 (281.98) and T_4 (271.67) respectively. At 4WAP and 6WAP, T_3 and T_4 recorded highest leaf area ratio of 231.13 and 193.56 respectively which were not significantly different (P<0.05) from those recorded from control and other treatment plots as indicated in table5, However, at 8 and 10WAP, T_2 and T_3 recorded highest leaf area ratio of 130.57 and 124.80 respectively which were not significantly different from the lowest 73.38 and 63.38 respectively? It was observed that there was sharp decline in the leaf area ratio from after 6WAP to 10WAP.

Effect of Treatment on Relative Growth Rate (gg-1 day-1) of Soybean

Table 6, revealed Relative growth rate of soybean as affected by treatments. At 2WAP, control recorded, highest relative growth rate (0.20375) which was significantly different from lowest (0.11475) recorded from T_3. Relative growth rate from T_4 (0.19250) was higher than those of T_2 (0.18025) and T_5 (0.1635).

At 4 and 6WAP, the T_5 and T_2 recorded the highest relative growth rate of 0.26575 and 0.16575(gg^{-1} day^{-1}) respectively which were not significant different from the lowest (0.13735$gg^{-2}day^{-1}$) and 0.06875$gg^{-1}day^{-1}$) recorded from control and T_3 as shown in table6. Also at 8 and 10WAP, it was the same trend were T_5 and T_2 respectively recorded the highest relative growth rate of 0.20525($gg^{-1}day^{-1}$) and 0.17715($gg^{-1}day^{-1}$) which were not significant different from the lowest 0.19275($gg^{-1}day^{-1}$) and 0.13850($gg^{-1}day^{-1}$) was from control and T_3 as indicated in table6. It was observed that T_2 and T_5 have performed better than other treatment as the time progress.

Effect Treatment on Net Assimilation Rate (gcm-^{2}day-^{1}) of Soybean

The result of Net assimilation rate as shown in Table 6, showed that at 2WAP, The T_2 recorded the highest Net Assimilation Rate (NAR) of 0.011250 g-cm^{-2}/day^{-1} which was not significantly different (P<0.05) from lowest NAR (0.008500 (gcm^{-2}/day^{-1}) recorded from T_5. The Net Assimilation rates recorded from control are at per with that of T_4 as indicated in Table 7. Whereas at 4WAP, T_5 recorded the highest value of NAR (0.006500) (gcm^{-2}/day^{-1}) which was significantly different (P<0.05) from the lowest (0.001375 gcm^{-2}/day^{-1}) recorded from control. T_2 was found to perform better than T_4 and T_3 and control although statically not significant. Similarly, at 6WAP Treatment$_2$ recorded higher NAR (0.00500 gcm^{-2}/$_{day-}$^{1}) which was significantly different (P<0.05) to lowest recorded from T_4 (0.000650 gcm^{-2}/day^{-1}). Also, $T_5$was observed to recorded the NAR (0.002750gcm^{-2}/day^{-1}) that was not significantly different (P<0.05) from control (0.000950 and T_3 (0.001450g-cm^{-2}/day^{-1}). At 8WAP and 10WAP, T_{5c} recorded the highest NAR values of 0.03750 and 0.004475 cm-^{2}/day^{-1} respectively which were significantly different (P<0.05) from the lowest (0.001775 and 0.002500gcm^{-2}/day^{-1}) respectively as indicated in Table 7.

Effect of Treatment on Shoot Dry Weight (G) of Soybean

The result on Table 8 revealed that there was no significant difference in shoot dry weight throughout the experiment. At 2WAP and 4WAP, T_3 and T_5 were found to have the highest shoot dry weight of 0.050025 (g) and 1.4693 (g) respectively which were not significantly different (P<0.05) from the shoot dry weight (0.36300 (g) and 0.7183g) recorded from controls respectively. Similarly, at 6 and 8 WAP, T_2 and T_5 recorded the highest shoot dry weights (2.0358g and 8.573g respectively) which were not significantly different(P<0.05) from the lowest (0.6253g and 3.3865g) respectively) recorded from T_3 at both periods. However at 10 WAP, T_2 recorded the highest shoot dry weight (10.117g) compare to the lowest (5.491g) recorded from control and T_3, which was statistically not significant. It was observed that T_2 and T_5 have better shoot dry weights value towards the maturity stage than other treated plots.

Effect of Treatment on Yield and Yield Components

The result of yield analysis in Table 9 revealed that number of pod was significantly influenced by treatments regimes. T_4 produced significantly (P<0.05) higher number of pods (85.750) than the number of pods from control plots (62.250). This was followed by $T_{5,}$ which produced 85.280 of pods. While T_3 was greater than T_2 in number of pods produced as indicated in Table 9.

Mean weight of 100 seeds was not statistically different among the treatments. T_3 recorded the highest seed weight of 1.7571g, which was statistically different from control with 16.006g. This was followed by T_2 with mean weight of 17.473g then T_4 with 17.385g. Among treated plots T_5 recorded the lowest mean seed weight (16.457).

Similarly, the yield result showed that T_2 gave the highest yield of 1002.99kg/ha which was not statistically different (P<0.05) from the lowest (909.45kg/ha) recorded from control.

However, T_5 recorded the lowest yield (934.69kg/ha) among the treated plots.

Effect of Treatment on the Proximate Composition of Soybean Seed

Moisture Content

The result presented in Table 10, shows that there was significant difference at (P<0.05) among the treatments. T5 recorded significantly higher moisture (4.125%) than control (3.855%). This was followed by T_2 which have 4.0356 of moisture which was significantly different (P<0.05) compare to control and other treated plots (Table 10).

Crude Protein

In Crude Protein analysis, T_3 was observed to significantly produce higher crude protein of 21.325% than the control (18.165%). Among the treated plots, T_2 has the lowest crude protein

(18.495%) which was significantly different ($P<0.05$) from T_4 (20.065%) and T_5 (19.420%), as shown in Table 10.

Crude Fibre

Crude fibre was significantly higher in T_3 (5.170%) than lowest recorded in T_5 (4.105g) followed by 4.485g fibre recorded from control. However, T_2 save significantly higher crude fibre (4.570g) than that recorded from T_4 (4.865g).

Crude Fat

Table 10, result showed that the control recorded the lowest Crude fat (16.380%) which was significantly different ($P<0.05$) from the highest crude fat (18.250%) recorded from T_3. T_2 gave greater crude fat (17.620%) than T_4 (17.480%) and T_5 (17.380%) which was significantly different at $P<0.05$.

Ash Content

It was also observed that Treatment$_3$ which is honey sticker of inoculant significantly recorded higher Ash Content (4.820%) than the lowest (4.055%) recorded from control plots. This was followed by T_2 (4.230) %, then T_4 and T_5 in that order. As shown in table 10.

Carbohydrate Content

In this study, percentage carbohydrate content of the seed of soybean was significantly influenced by Nodumax Sticker. Control was observed to record highest carbohydrate content (52.785g) which was significantly different ($P<0.05$) from the lowest recorded from T_3 (46.625%). This was followed by T_2 (51.385%), then T_5 (50.670%) and T_4 (49.150%) in that order, as indicated in Table 10.

Energy Value

Energy Value was significantly influenced by the treatments T_5 was observed to give highest energy value of 437.363kcal which was significantly different ($P<0.05$) from the lowest (432.290 kcal) from control Energy Value (436.750 kcal) from T_2 was significantly different from energy (435.825 kcal and 435.64 kcal respectively) recorded from T_3 and T_4.

DISCUSSION

The results showed that the used of adhesive agents influenced inoculation of soybean seeds which improved growth, nodulation and yield of soybean. However, the use of gum Arabic and sugar as adhesive agent influenced more in all the vegetative parameters measured compared to the control and other adhesive agents.

Seed inoculation enhanced seed emergence and seedling vigour of soybean. However, the rate of enhancement varied with adhesive agent used. This corresponds to work of (Lugtenberg*et al.*, 2004 and Gholami*et al.*, 2009) that bacterial inoculants are able to increase plant growth germination rate, improve seedling emergence response to external stress factor and protect plant from diseases.

These finding may due to the increase in synthesis of hormones like gibberellins, which would have triggered the activity of specific enzymes that promote early germination such as -amylase, which have brought an increase in availability of starch for assimilation. Besides, significant increase in seedling vigour would have occurred by enhanced synthesis of auxins (Bharathi *et al.,* 2004).

In this present study, carrier based Nodumax inoculation significantly improved growth and yield parameters of soybean viz, plant height, leaf area, leaf area index, leaf area ratio, Relative Growth Rate (RGR) and Net Assimilation Rate (NAR). This increment in vegetative growth parameters might be due to increased activity of rhizobia enhanced by different adhesive agents. This improvement in growth characteristics of soybean in carrier based Nodumax inoculation might be attributed to the fact that Nodumax peat inoculant contain elements that are involved in various metabolic process of Rhizobia which in turn improved microbial efficiency. This is in line with Malusa*et al*. (2012), and Salman *et al.* (2017), who reported that application of carriers that serves as growth medium for PGPR by providing optimal condition.

The increase in Leaf Area, Leaf Area Index and Leaf Area Ratio recorded in inoculated plants in this study could be attributed to the enhanced plant height growth of such plants. This result conforms with the findings of Mallik *et al*. (2006) and Lamptey *et al*. (2014), who reported that inoculation promotes growth factors such as production of larger leaves.

Plant heights was enhanced by inoculation of Nodumax on soybean seeds compare to untreated, the variation noticed in heights could be due to properties of various adhesive agents used. However, gumarabic enhanced plant height more than any other treatment this was followed by sugar. We suggest that activities of microorganism and indigenous rhizobium and other elite microbes could have been enhanced more by gumarabic and sugar, culminating in taller plant height and other growth parameters observed in this study. Plant height as influenced by inoculation with Nodumax consequently will out-compete weeds, in order to capture more light and other growth resources. This is in agreement with Hernendiez and Cuevas (2003), and Lamptey *et al.* (2014) who reported that inoculation increased plant height.

The obtained result showed that Relative Growth Rate (RGR), Net Assimilation Rate (NAR) and shoot dry were greatly improved by Nodumax inoculation using gum arabic as adhesive agent. This increment could be due to increase in Nitrogen Fixation, which enhanced the photosynthetic activities of inoculated plant thereby increasing assimilation of photosynthates into the matrix of plant tissue. Similar observations reported in other studies were inoculation of chick pea with rhizobia increased plant growth, ground dry matter, number of pods, seed yield and Nitrogen fixation under various climatic conditions (Fatima *et al.,* 2008). Also, this conform with the study conducted by Stefanescu and Palanciuc, (2000) which revealed that shoot dry matter of the inoculated treatments were significantly greater than that of control as a result of increase in nodulation.

The ultimate test for the performance of adhesive agents (gum Arabic, sugar, honey, powdered milk) is the assessment of nodulation and plant yield. Inoculation with Nodumax significantly promotes growth characteristics, increased pod number and yield of soybean. This suggests that inoculation with Nodumax inoculant could improve nitrogen nutrition, promotes vegetative growth, particularly root growth, as well as benefit root uptake of minerals and water from soil by Soybean. Similar observations reported in other studies were inoculation of chickpea with rhizobia increased plant growth, ground dry matter, number of pods, seed yield and nitrogen fixation under various climate conditions (Fatima *et al.*, 2008; Lamptey *et al.*, 2014)

Proximate composition was improved by Nodumax inoculation. Inoculation significantly increases fat, Fibre and protein contents, this conforms with work of Elsheikh & Ahmed (2000) who reported that inoculation with Rhizobium and/or Brady rhizobium significantly increased the fat and the crude fibre content of faba bean and reduced carbohydrate content. The decrease in the carbohydrate content in the seeds of inoculated Soybean could be attributed to the high concentration of nitrogen available to the plant which increased the protein content which resulted in reduction of the carbohydrate content

The result suggests that soybean inoculation with Nodumax inoculant can improve the seed composition and quality. (Abdelgania *et al*., 1999) have reported similar finding on fenugreek cultivars.

CONCLUSION

Soybean seeds inoculation with Nodumax a commercial inoculant could improve crop establishment produced more vegetative, increase higher shoot and higher relative growth rate and net assimilation rate, produced more pods, which resulted in an increase soybean yield. The study therefore recommends that for increase yield, soybean seeds should be inoculated before planting due to poor soil fertility occasion by erosion and other environmental factors. Also, for higher growth indices, nodule numbers shoot and root biomass, and increase yield, adhesive agents like gum Arabic honey, powdered milk and sugar should be used. Considering the fact that gum Arabic is not always available and expensive, local farmers should be encouraged to use honey, powered milk and sugar or any other local sticky agent that will not be harmful to the rhizobia for inoculation before planting.

Nodumax inoculant is indeed easy, eco-friendly and therefore should be encourage for use by local farmers for soybean and other legumes production in Nigeria.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

Acknowledgments

The authors are thankful to Mr A. Longa of International Institute of Tropical Agriculture Ibadan for technical support to this study.

REFERENCES

Adesemoye, A., Torbert, H. and Kloepper, J. (2009). Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. *Microbial Ecology*, 58:921-929, https://doi.org/10.1007/s00248-009-9531-y

Abdelgania, M.E, Elsheikha, E.A.E and N.O. Mukhtarb (1999). Effect of Rhizobium Inoculation and Chemical Fertilization on seed Quality of Fenugreek. *Food Chemistry*, 64 (30):289-293. https://doi.org/10.1016/S0308-8146(98)00098-3

Ali, N. (2010). Soybean Processing and Utilization, In: *The soybean: botany, production and uses*, Singh, G., (Ed.) 345-362, *CAB International, UK.* https://doi.org/10.1079/9781845936440.0345

Alves, V.S., Pimenta, D.C., Sattlegger, E. and Castilho, B.A. (2004). Biophysical characterization of Gir 2, a highly acidic protein of *Saccharomycescerevisiae* with anomalous electrophoretic behavior. *Biochem. Biophys. Res. Commun. 314(1):229-34.* https://doi.org/10.1016/j.bbrc.2003.12.086

Alquéres, S., Meneses, C., Rouws, L., Rothballer, M., Baldani, I., Schmid, M. and Hartmann, A. (2013). The bacterial superoxide dismutase and glutathione reductase are crucial for endophytic colonization of rice roots by Gluconacetobacterdiazotrophicus PAL5. Mol Plant-Microbe Interact 26:937- 945. https://doi.org/10.1094/MPMI-12-12- 0286-R

Bacon, C.W. and Hinton D.M. (2006). Bacterial endophytes: the endophytic niche, its occupants, and its utility. In: Granamanickam S.S. (ed). *Plant associated bacteria. Springer, the Netherlands, pp. 155-194.* https://doi.org/10.1007/978-1-4020-4538-7_5

Badri, D.U. and Vivanco, J.M. (2009). Regulation and function of root exudates. *Plant, Cell and Environment 32, 666-681.* https://doi.org/10.1111/j.1365-3040.2009.01926.x

Bai, H.P., Weir, T.L., Perry, L.G., Gilroy, S. and Vivanco, J.M. (2006). The role of root exudates in rhizosphere interactions with plants and other organisms. *Annual Rev Plant Biology* 57:233- 266. https://doi.org/10.1146/annurev.arplant.57.032905.105159

Bharathi, R.R., Vivekananthan, S. Harish, A. Ramanathan and R. Samiyappan (2004). Rhizobacteria-based bio-formulations for the management of fruit rot infection in chillies. *Crop Prot.* 23: 835-843. https://doi.org/10.1016/j.cropro.2004.01.007

Beauregard, P.B., Chai Y, Vlamakis H, LosickR,and R.Kolter (2013)Bacillus Subtilis biofilm induction by plant polysaccharides. *Proc. Natl. Acad. Sci. U.S.A. 110, E1621-E1630.doi:10.1073/Pnas. 1218984110.*

Cai, H., Kauffman S., Naider, F. and J.M. Becker (2006). Genome wide screen reveals a wide regulatory network for di/tripeptide utilization in *Saccharomycescerevisiae*. *Genetics 172(3): 1459-76.* https://doi.org/10.1534/genetics.105.053041

Cai, T., Cai, W., Zhang J, Zheng, H., Tsou, A.M., Xiao, L., Zhong, Z. and Zhu, J. (2009). Host legume-exuded antimetabolites optimize the symbiotic rhizosphere. *Mol Microbiol* 73:507-517. https://doi.org/10.1111/j.1365-2958.2009.06790.x

Cai, Z., Kastell, A., Knorr, D. and Smetanska I (2012) Exudation: An expanding technique for continuous production and releaseof secondary metabolites from plant cell suspension and hairy root cultures. Plant cell *reports* 31:461-477. https://doi.org/10.1007/s00299-011-1165-0

Danhorn, T., and Fuqua, .C. (2007). Biofilm formation by plant associated bacteria. *Annu. Rev. Microbiol*401-422. https://doi.org/10.1146/annurev.micro.61.080706.093316

Dimkpa, C.O., Merten D., Svatos A., Büchel G., KotheE.(2009) Siderophores mediate reduced and increased uptake of cadmium by *Streptomyces tendae* F4 and sunflower (*Helianthus annuus*), respectively. *Journal of Applied Microbiology*. ;107:1687–1696. https://doi.org/10.1111/j.1365-2672.2009.04355.x

Fatima, Z, Bano, A., Sial, R. and Aslam, .M. (2008). Response of chicken to plant growth regulators on nitrogen taxation and yield. *Pakistan Journal of botany* 40 (5):2005-13.

Gholami, A., S. Shahsavani, and S. Nezarat (2009).The effect of Plant Growth Promoting Rhizobacteria (PGPR) on Germination Seedling Growth and Yield of Maize. *International Journal of Agriculture and Bio System Engineering*, 3(1): 9-14.

Glick, B.R. (2012). Modulation of plant ethylene levels by the bacterial enzyme ACC deaminase. *FEMS Microbiology letters* 251, 1-7. https://doi.org/10.1016/j.femsle.2005.07.030

Gray, E.J. and D.L. Smith (2005). Intracellular and extracellular PGPP: Commonalities and distinctions in the plant. Bacterium signaling processes. *Soils Biol. Biochem.,* 37:395-412.

Grover, A., Kamins M.A., Martin I.M., Davis, S., Haws, K., Mirabito, A.M., Mukherjee, S., Pirouz, D. and Rapp, J. (2011). From use abuse: When everyday consumption behaviours morph into addictive consumption behaviours. *Journal of Research for consumers,*

19:1-8. https://doi.org/10.1016/j.soilbio.2004.08.030

Hernandez, M, and Cuevas, F. (2003). The effect of inoculating with arbuscular mycorrhiza and Brady rhizobium stains on Soybean (*Glycine Max* (L.) Merrill) crop development. *CultivosTropicales,* 24(2):19-21

Hungria, M.; Loureiro, M., Mendes, I., Campo, R. and Graham, P. (2005). Inoculant preparation, production and application, In: *Nitrogen fixation in agriculture, forestry,ecology, and the environment,* Werner, D. & Newton, W. (Eds.), 223-253, Springer, ISBN 10 1-4020-3542-X , Netherlands. https://doi.org/10.1007/1-4020-3544-6_11

Lamptey, S. Ahiabor, B.D.K., Yeboah, S. and D. Osei (2014). Effect of Rhizobium inoculants and reproductive growth stage on shoot Biomass and Yield of Soybean *(Glycine*

Max (L.) Merrill). *Journal of Agriculture Science* 6(5)44-54. https://doi.org/10.5539/jas.v6n5p44

Lugtenberg, B., T. Chin-A-Woeng and G. Bloemberg (2004) Microbe-plant interactions: principles and mechanisms. *Antonie Van Leeuwenhoek*, 81: 373-383. https://doi.org/10.1023/A:1020596903142

Lynch, M. (1990). The rate of morphological evolution in mammals from the standpoint of the neutral expectation. *American Naturalist* 136:727-741. https://doi.org/10.1086/285128

Hernandez, M, and Cuevas, F. (2003). The effect of inoculating with arbuscular mycorrhiza and Brady rhizobium stains on Soybean (*Glycine Max* (L.) Merrill) crop development. *CultivosTropicales* 24(2): 19-21

Malusa, E, L. Sas-Paszt and S. Ciesielska (2012). Technologies for beneficial microorganisms inocula used as bio-fertilizers. *Sci: world. S.*P 1.1-13. https://doi.org/10.1100/2012/491206

Malik, M. F. A., Qureshi, A. S., Ashraf, M., and Ghafoor, A. (2006). Genetic variability of the main yield related characters in soybean. *Intl. J. Agric. and Biol., 8*(6), 815-819.

Meneses*et al.* (2011). Minimization of thermal impact by application of electrode cooling in a co-linear PEF treatment chamber. *J. Food Sci.* 76, E536-E543.doi:10.1111/j.1750-3841.2011.02.368.x.

Ogoke, I.J. Egesi C.N. and J.C. Obiefuna (2003*). A Review of some Non-Destructive Linear measurement Procedures for Leaf Area Determination in Crops. Int. J. Agric. Rural Dev. 4: 74-80.* https://doi.org/10.4314/ijard.v4i1.2548

International Institute of Tropical Agriculture (IITA, 2015). *The bulletin,* No 2259, pp19- 23, IITA,Ibadan ,Nigeria

FAO STAT. (2011). Food and Agriculture Organization Statistical Database, access on August 30, available from :<http://faostat.fao.org>

Liu, K. (1999). Chemistry and nutritional value of Soybean components, In: *Soybeans: Chemistry, Technology and Utilization*, Liu, K., pp (25-94), Aspen Publisher, ISBN 0-8342-1299-4, New York.

Salman, Shalgad, Muhqmmad Yahya, Zahir Ahmad Zahir, Naeem Asghar and Usman Khalid Chaudhry (2017). Comparative effective of different carriers to improve the efficacy of bacterial consortium for enhancing wheat production under salt effected field conditions. *Pak. J. Bot*. 49(4):1523-1530.

Journal of Agriculture and Food Sciences **Ogbuehi H.C.**
Volume 18, Number 2, October 2020, pp 54 - 72 .

APPENDIX

Table 1: Effect of Treatment on the Percentage of Emergence

Treatment	Percentage Emergence (%)
T_1 - Control	71.88[a]
T_2 – Gumarabic	78.44[a]
T_3 - Honey	55.48[a]
T_4 - Powder Milk	54.64[a]
T_5 – Sugar	82.82[a]

Means in the same column with the same letter having the same letters are not significantly different (P<0.05)

Table 2: Effect of Treatment on Plant Height (cm)

	MEAN PLANT HEIGHT (cm)				
Treatment	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	15.00 [a]	21.500	24.050[b]	36.125[a]	47.350[b]
T_2 – Gumarabic	14.125 [a]	22.000[a]	30.000[ab]	38.200[a]	48.575[b]
T_3 - Honey	13.925 [a]	24.500[a]	31.475[ab]	37.750[a]	54.500[ab]
T_4 - Powder Milk	10.975[b]	20.350[c]	37.350[a]	43.750[a]	48.175[b]
T_5 – Sugar	12.175[bc]	25.825[a]	34.150[a]	46.675[a]	57.850[a]

Means in the same column with the same letter having the same letters are not significantly different (P<0.05)

Table 3: Effect of Treatment on Leaf Area of Soybean (cm^2)

	MEAN LEAF AREA (CM^2)				
Treatment	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	132.77 [a]	130.74[b]	209.32[a]	427.2[a]	635.8[a]
T_2 - Gumarabic	154.79 [a]	202.33[ab]	202.67[a]	439.0[a]	794.8[a]
T_3 - Honey	183.63[a]	345.74[a]	250.01[a]	303.1[a]	737.6[a]
T_4 - Powder Milk	113.69[a]	239.26[ab]	281.14[a]	705.7[a]	746.5[a]
T_5 – Sugar	106.44[a]	228.92[ab]	289.16 [a]	709.7[a]	817.0[a]

Means in the same column with same letters are not significantly different (P<0.05)

Table 4: Effect of Treatment on Leaf Area Index (LAI) of Soybean

MEAN LEAF AREA INDEX					
Treatments	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	1.6840[a]	0.9403[a]	0.6878[a]	0.2430[c]	0.3348[a]
T_2 – Gumarabic	1.5535[a]	0.9878[a]	0.7123[a]	0.5615[ab]	0.480[a]
T_3 - Honey	1.1950[a]	1.1393[a]	0.8918[a]	0.6375[a]	0.6275[a]
T_4 - Powder Milk	1.4675[a]	0.9450[a]	0.8348[a]	0.3412[bc]	0.3799[a]
T_5 – Sugar	1.0220[a]	0.8433[a]	0.5775[a]	0.3450[bc]	0.4170[a]

Means in the same column with the same letter having the same letters are not significantly different (P<0.05)

Table 5: Effect of Treatment on Leaf Area Ratio of Soybean

MEAN LEAF AREA RATIO					
Treatment	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	299.12[a]	190.78[a]	168.38[a]	73.38[a]	63.38[a]
T_2 – Gumarabic	351.75[a]	217.91[a]	173.01[a]	130.57[a]	112.93[a]
T_3 - Honey	326.87[a]	231.13[a]	145.12[a]	126.22[a]	124.80[a]
T_4 - Powder Milk	271.67[a]	217.19[a]	193.56[a]	116.55[a]	84.81[a]
T_5 – Sugar	281.98[a]	176.88[a]	148.77[a]	109.62[a]	116.36[a]

Means in the same column with same letters are not significantly different (P<0.05)

Table 6: Effect of Treatment on Relative Growth Rate ($gg^{-1}day^{-1}$) of soya bean

MEAN RELATIVE GROWTH RATE ($gg^{-1}day^{-1}$)					
TREATMENT	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	0.20375[a]	0.13735[a]	0.1150[a]	0.19275[a]	0.16950[a]
T_2 – Gumarabic	0.18025[ab]	0.16575[a]	0.16575[a]	0.18750[a]	0.17150[a]
T_3 - Honey	0.11475[b]	0.19175[a]	0.06875[a]	0.14075[a]	0.13850[a]
T_4 - Powder Milk	0.19250[a]	0.16885[a]	0.10700[a]	0.19775[a]	0.16600[a]
T_5 – Sugar	0.16325[ab]	0.26575[a]	0.11500[a]	0.20525[a]	0.15925[a]

Means in the same column with the same letters are not significantly different (P<0.05)

Journal of Agriculture and Food Sciences **Ogbuehi H.C.**
Volume 18, Number 2, October 2020, pp 54 - 72 .

Table 7: Effect of Treatment on Net Assimilation Rate (gcm^{-2}day^{-1})

MEAN NET ASSIMILATION RATE					
Treatment	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	0.00975_a	0.001375_b	0.000950_b	0.001775_a	0.002750_a
T_2 – Gumarabic	0.011250_a	0.004250_{ab}	0.00500_a	0.013750_a	0.004500_a
T_3 - Honey	0.00900_a	0.001750_b	0.001450_b	0.003250_a	0.002500_a
T_4 - Powder Milk	0.009750_a	0.002500_b	0.000650_b	0.003000_a	0.003500_a
T_5 – Sugar	0.008500_a	0.006500_a	0.002750_{ab}	0.003750_a	0.004475_a

Means in the same column having the same letters are not significantly different (P<0.05)

Table 8: Effect of Treatment on Shoot Dry Weight(g) of Soybean

MEAN SHOOT DRY WEIGHT (G)					
Treatment	**2WAP**	**4WAP**	**6WAP**	**8WAP**	**10WAP**
T_1 - Control	0.36300^a	0.7183^a	1.0475^a	5.554^a	5.491^a
T_2 – Gumarabic	0.38450^a	0.7730^a	2.0358^a	7.898^a	10.117^a
T_3 - Honey	0.50025^a	1.0713^a	0.6253^a	3.3865^a	5.491^a
T_4 - Powder Milk	0.36300^a	0.8073^a	1.3690^a	6.500^a	6.867^a
T_5 – Sugar	0.43125^a	1.4693^a	1.0210^a	8.573^a	8.669^a

Means in the same column having the same letters are not significantly different

Table 9: Effect of Treatment on Yield and Yield Component

Treatment	**Mean No. of pod**	**Mean 100 seed weight(g)**	**Mean yield (kg/ha)**
T_1 - Control	62.250^B	16.006^a	909.45^a
T_2 – Gumarabic	73.835^{ab}	17.473^a	1002.99^a
T_3 - Honey	77.750^{ab}	17.571^a	998.35^a
T_4 - Powder Milk	85.750^a	17.385^a	987.78^a
T_5 – Sugar	85.280^a	16.457^a	934.69^a

Means in the same column with the same letter are not significantly different (P<0.05)

Journal of Agriculture and Food Sciences
Volume 18, Number 2, October 2020, pp 54 - 72 .

Table 10: Effect of Treatment on Proximate Composition

Treatment	M.C. (%)	Crude protein (%)	Crude Fibre (%)	Crude fat (%)	CHO (%)	Energy (kcal)	Ash (%)
T_1 - Control	3.855^{d}	18.495^{d}	4.485^{d}	16.380^{e}	52.785^{9}	432.290^{e}	4.055^{e}
T_2 – Gumarabic	4.035^{d}	18.165c	4.570^{c}	17.620b	51.385b	436.750^{b}	4.230b
T_3 - Honey	3.835^{d}	21.325^{a}	5.170^{a}	18.225^{a}	46.625^{a}	435.825^{c}	4.820^{a}
T_4 - Powder Milk	3.950^{c}	20.065^{b}	4.865^{b}	17.480^{c}	49.510^{d}	435.64^{d}	4.125^{d}
T_5 – Sugar	4.125^{a}	19.420^{c}	4.105^{e}	17.385^{d}	50.670^{c}	437.363^{a}	4.17^{c}

Means in the same column with the same letter are not significantly different (P<0.05)