Open American Journal of Agricultural Research
Vol. 2, No. 1, April 2015, pp. 1 - 7
Available online at http://scitecpub.com/Journals.php

**Research article**

# Effect of different Phosphorus sources and methods of application on growth, nodulation and yield of soybean (*Glycine max* (L) Merr.)

**Ahlam E. Ahmed, Alawia O. Hassan and Elamin Y. A. Raddad**

Agricultural Research Corporation (ARC), P.O. Box 126, Wad Madani, Sudan.
(E-mail: aelsammani2003@yahoo.com)



## Abstract:

Afield experiment was conducted in the Sudan for two seasons 2011and 2012 at Gezira Research Station Farm which is the biggest Agricultural Research Corporation (ARC) stations. The main objective of this experiment was to investigate the effect of different phosphorus sources and methods of application on nodulation, growth and yield of soybean. Three phosphorus sources (Triple superphosphate (TSP), NPK and Diammonium phosphate (DAP)) were used with two methods of application (broadcasting and bedding), in addition to control. Soybean variety SY1448-11 was fertilized with the above mentioned phosphorus fertilizers at the rate of 43kg$P_2O_5$/ha (1P).The treatments were assigned in RCBD with four replicates. The shoot dry weight, grain and straw yields of soybean were significantly increased in response to the application of different phosphorus sources. All phosphorus sources increased the soybean nodulation and strain effectiveness. DAP fertilizer gave the highest values in all parameters measured. The bedding method produced highest grain and straw yields. These results recommended the fertilization of soybean by DAP at the rate of 43kg $P_2O_5$/ha using the bedding method. Other alternative include TSP as a source and broadcasting as a method if the recommended choice is not at hand. Economic evaluation was conducted to rank the most effective phosphorus fertilizers and method of application to reach the most economic and profitable level .The highest MRR was obtained from DAP fertilizer and bedding method (2360%).

**Keywords:** Soybean, phosphorous, method of application.

## Introduction

Legumes play an important part in the diets of most of the people of developed and developing countries. The residual effect of legumes on subsequent crops is one of the most important factors to be considered when they are introduced into a farming system. In addition, legumes are known for their ability to reduce atmospheric $N_2$ to a biologically useful form.

Soybean or soya bean *(Glycine max*) is a species of legume native to East Asia, widely grown for its edible bean which has numerous uses. The plant is classed as an oil crop rather than a pulse by UN Food and Agricultural Organization. Soybean is nodulated by the bacteria *Bradyrhizobium japonicum*. All experiments conducted in the Gezira Research Farm showed soybean nodulaion indicating the presence of infective indigenous strain in the Gezira soil.

Phosphorus (P) is vital to plant growth and is found in every living plant cell. It is involved in several key plant function including energy transfer, photosynthesis, nutrient movement within the plant and transfer of genetic characteristics from one generation to another. Phosphorus is a limiting factor to plant growth and productivity on 40% of the world arable soil (Vance, 2001).

Phosphorus fertilizer sources were divided into organic and inorganic fertilizers. Practically all inorganic P fertilizers come from phosphate rock (PR) which is a naturally occurring sedimentary rock composed largely of calcium phosphate minerals (apatite**).** Most conventional commercial P fertilizers are made by reacting PR with sulfuric acid to produce phosphoric acid (green or wet process acid). The phosphoric acid is further reacted with ammonia (ammoniation) to produce ammonium phosphate fertilizers such as diammonium phosphate (DAP) and monoammonium phosphate (MAP). Production of ammonium polyphosphate fertilizer (APP) requires dehydration and polymerization of phosphoric acid prior to ammoniation (Stewant, W.M., 2009). Biological $N_2$ fixation represents the major source of N input in agricultural soils. It increased soil fertility and more residual N for succeeding crops (Hardarson *et al.*, 1989).

In legume, phosphorus deficiency specially affects symbiotic fixation of N2 by limiting growth and survival of rhizobia (O'Hara et al., 1988), nodule formation (Drevon and Hartwig 1997) and functioning (Tang et al., 2001a), and host plant growth (Tsvetkova and Georgiev, 2003). In addition, phosphorus deficiency has previously been reported to decrease nodule mass more than host growth in soybean (Drevon and Hartwig, 1997).

There are different methods of phosphorus application, broadcasting, banding or bedding and drilling. Bolland 2001 recommended that in faba bean the phosphorus was placed with seed (drill) and sow at 5 to 8 cm deep in row up to 38 cm apart.

In Gezira soil P form insoluble complexes with cations and it is incorporated into organic matter due to microbial activity or fixed in the soil. As a result, P uptake by the plants is often constrained by the low solubility of P in the soil. Therefore the objective of this study was to investigate the effect of different sources of phosphorus and methods of application on nodulation, growth and yield of soybean.

## Materials and Method:

This experiment was conducted for two seasons 2011and2012 at Gezira Research Farm (GRSF), in soil classified as fine semectatic, isohyperthermic, chromic hapluster and correlated to Remeitab soil series, non-sodic phase with vertisolic limitation ( NRCS, 2003).The treatments were combinations of three phosphorus sources , TSP (46% $P_2O_5$), NPK (15 % $P_2O_5$: 15 % N) and DAP (46 % $P_2O_5$:18% N) and two methods of application (broadcasting and bedding) in addition to control without P form the base of the research. One level of phosphorus (1P) for the three phosphorous fertilizers was applied this equivalent to 93.4, 286.6 and 93.4 kg/ha of DAP, NPK and TSP respectively. The treatments were assigned in RCBD with 4 replicates. Soybean variety SY1448-11 was sown in ridges with inter and intra row spacing of 80 and 5 cm respectively. The soybean seeds were sown in the first week of July in both seasons. Phosphorus was applied at sowing. The phosphorus fertilizers were broadcasted by hand beside the seed or bedded in the soil, 5-10 cm beside the seeds and 5cm deep into the soil. Plant samples were taken from each treatment to determine plant dry weight, nodule number and dry weight. Grain and straw yield were determined at harvest. The harvested area was 6.4 $m^2$. Analysis was performed using MSTATC software. Economic evaluation was conducted using partial budget techniques to calculate and compare the economic return and net benefits of the different methods of application.

## Result and discussion

## Grain and straw yield:

Generally application of phosphorus, regardless of its source, increased significantly (P= 0.001) the soybean grain yield in both season (Table1and 3). In both season there was no significant difference between the yield of NPK and TSP fertilizers, however the difference is clear between DAP and TSP yield in the first season and between DAP and NPK yield in the second season. The DAP fertilizer produced the highest seed yield in both seasons (2263 and 1674 kg/ha) compared to the other phosphorous sources this may be due to that DAP contain 18% nitrogen act as starter dose and contain high percentage of phosphorus 46% $P_2O_5$ (Table1and 3). The triple superphosphate (TSP) gave the highest grain yield (1284) compared to NPK in the second season this may be because of higher percentage of $P_2O_5$ found in the TSP; the plant was recovered more in case of TSP because it contain high $P_2O_5$ percentage. The above results were similar to those reported by Kamanga,et al., 2010 who found that the application of P fertilizers significantly (P=0.05)increased legume grain yields particularly with velvet bean and soybean. Regardless of the types of phosphorous fertilizers used the bedding method produced significantly (0.01) the higher grain yield compared to broadcasting method in both seasons. According to the main effect the bedding method increased the grain yield by 8% and 16% in the first and second season, respectively compared to broadcasting method (Table 2and 3). Also the DAP fertilizer gave higher yield in case of bedding method compared to that obtained by broadcasting method. Application of phosphorus fertilizers increased soybean straw yield in both seasons (Table 2 and 3). Bedding the P fertilizers into the soil increased the soy bean straw yield and produced the highest straw yield regardless the P sources. The DAP fertilizers produced higher straw yield by bedding method and increased the straw yield by 13% and 46% compared to broadcasting method in the first and second season, respectively.(Table 2 and3 ) The combine analysis for two seasons showed that soybean responded positively and significantly to bedded phosphorus fertilizers (Table 4).

## Plant growth:

Regardless of the types of phosphorous fertilizers or method of application used fertilization of soybean by P fertilizers affected the plant growth and produced highest plant dry weight in both season compared to unfertilized one. The DAP fertilizer increased the plant dry weight significantly in both season and gave highest dry weight compared to control and to the other phosphorus fertilizers. In the second season, the three phosphorus fertilizers significantly differed in their plant dry weight. According to the main effect in the second season the TSP, NPK and DAP fertilizers increased the plant dry weight by 31%, 50% and 75% respectively (Table 1and3). The Phosphorus is a component of the complex nucleic acid structure of plants, which regulates protein synthesis. Phosphorus is, therefore, important in cell division and development of new tissue (Robert 1954). The bedding method increased the uptake of phosphorus which is reflected in plant growth that lead to high plant dry weight in both seasons compared to broadcasting method. Regardless the source of phosphorus the bedding method increased the plant dry weight by 30.4%and 25% in season2011 and 2012 respectively compared to broadcasting method (Table 2 and 3).

## Nodulation:

Because of irregular irrigation, the plant samples were not taken at the optimum time and they were taken when the field was dry, therefore the data for the first season were excluded. Nodule number and nodule dry weight for the second season were shown in Figs. 1 and 2. It has been observed that nodules were present in soybean roots plants indicating the presence of indigenous strain in the soil, thus these strains were infective. The phosphorus fertilization increased the nodulation of soybean and strains effectiveness, and hence improved the biological nitrogen fixation. The effectiveness of strains is an important factor which determines the nitrogen fixed by soybean under favorable growing condition and well adapted cultivar (.Hardarson et al., 1994). Phosphorus fertilizer application significantly (P=0.05) increase nitrogen fixation up to 26.4kgP/ha.( Amba, etal., 2011) Nodule growth was more limited than shoot growth by P deficiency (Drevon and Hartwig, 1997).

## Economic analysis:

Partial budget analysis for different methods of application was presented in table 5, 6, 7, 8, and 9. All treatments gave positive net return except NPK with the two methods of application which gave negative net benefit due to the high cost of NPK fertilizer compared to the other two fertilizers TSP and DAP. For combined analysis, the MRR obtained from using DAP fertilizer with bedding method of application was 2360 % which means that, for every one SDG invested in the treatment, there was additional SDG23.6 benefit.

## Conclusion:

1- Fertilization of soybean by TSP, NPK or DAP at rate of 1P (43 kg $P_2O_5$ / ha) increased soybean growth, nodulation and yield.
2- The best phosphorus fertilizer was Diammonium phosphate fertilizer (DAP).
3- The bedding method was found to be better than broadcasting method.

## References

[1] Amba, A.A., Agbo, E.B., Voncir, N. and Oyawoye, M.O. (2011). Effect of phosphorus fertilizer on soil chemical properties and nitrogen fixation of legume at Bauchi. Continental J. Agricultural Science 5 (1): 39 – 44.

[2] Bolland, Mike.(2001)Faba bean, row spacing and method of applying fertilizers with other crops. Famnote 66.

[3] Drevon, J.J. and Hartwing, U.A. (1997). Phosphorus deficiency increases the argon-induced decline of nodule nitrogenase activity in soybean and alfalfa. Planta 21, (4), pp. 463-469.

[4] Hardarson, G. (1994). International FAO/IAEA programmes on biological nitrogen fixation. In Symbiotic Nitrogen fixation. Eds. PH Graham. M.J.Sadowsky and C.P.Vance. pp. 189 – 202. Kluwer Acadamic Publishers, Dordrecht, The Netherlands.

[5] Hardarson, G. M.Golbs and S.K.A. Danso. ( 1989). Nitrogen fixation in soybean (Clycine max.L. Merril) as affected by nodulation patterns. Soil Biol. Biochem. 21, 783- 787.

[6] Kamanga, B.C.G.; Whitbread, A.M.; Wall, P.; Waddington, S.R.; Almekinders, C.J.M. Giller, K.E. Famer evaluation of phosphorus fertilizers application to annual legumes in Chisepo, Central Malawi. African Journal of Agricultural Research 5 (2010)8. - ISSN 1991-637X - p. 668 - 680.

[7] Tsvetkova, G.E. and Georgiev, G.I. (2003). Effect of phosphorus nutrition on the nodulation, nitrogen fixation and nutrient use efficiency of Brady Rhizobium japonocum Soybean (Glycine max L. Merr.).symbiosis, Bulg. J. Plant physiol. Special issue, 331-335.

[8] Stewant, W.M. (2009). Phosphorus fertilizers source. Plant Nutrition No. 8.

[9] Vance, C.P. (2001). Symbiotic nitrogen fixation and phosphorus acquisition . plant nutrition in a world of declining renewable resource. Plant Physiol. 127.390-397

**Table 1:** Effect of different phosphorous sources on plant growth (g/plant), grain and straw yields (kg/ha) of soybean grown at Gezira Research Station farm during seasons 2011and 2012.

| Phosphorous fertilizers | Plant growth | | | Grain yield | | | Straw | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| TSP | 19 | 21 | 20.0 | 1933 | 1284 | 1609 | 2263 | 3447 | 2855 |
| NPK | 21 | 24 | 22.5 | 2092 | 1228 | 1660 | 2938 | 3584 | 3261 |
| DAP | 26 | 28 | 27.0 | 2263 | 1674 | 1969 | 3163 | 4188 | 3676 |
| Control | 10 | 16 | 13.0 | 1667 | 1072 | 1370 | 1675 | 2821 | 2248 |
| SE ± | 23.27 | 0.8 | | 58.7 | 92.8 | | 169.2 | 87.4 | |
| C.V. % | 1.59 | 10.6 | | 8.36 | 19.98 | | 18.8 | 15.11 | |

**Table 2:** Effect of different methods of application of phosphorous fertilizers on soybean grain and straw yield (kg/ha) and plant growth of soybean grown at Gezira Research Station farm during seasons 2011and 2012.

| Application method | Plant growth | | | Grain yield | | | Straw yield | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| Broadcasting | 16.8 | 20 | 18.4 | 1911 | 1217 | 1564 | 2975 | 3190 | 3083 |
| Bedding | 21.9 | 25 | 23.5 | 2065 | 1412 | 1739 | 3350 | 3830 | 3590 |
| SE + | 1.13 | o.6 | | 41.5 | 65.6 | | 119.7 | 132.5 | |
| C.V.% | 23.27 | 10.6 | | 8.36 | 19.98 | | 18.8 | 15.11 | |

**Table 3.** The interaction effect of phosphorus sources and application methods on soybean grain and straw yields (kg/ha) and plant growth (g/plant) of soybean grown at Gezira Research Station farm during seasons 2011and 2012.

| Phosphorous fertilizer | Season 2011 | | | | | |
|---|---|---|---|---|---|---|
| | Plant growth | | Grain yield | | Straw yield | |
| | Method of application | | | | | |
| | Broadcasting | Bedding | Broadcasting | Bedding | Broadcasting | Bedding |
| TSP | 15.5 | 22.9 | 1856 | 2011 | 2150 | 2375 |
| NPK | 19.2 | 24.3 | 1992 | 2187 | 2700 | 3175 |
| DAP | 22.2 | 29.8 | 2129 | 2188 | 2975 | 3350 |
| SE ± | 2.25 | | 83.1 | | 239.33 | |
| C.V. % | 23.27 | | 8.36 | | 18.8 | |
| Season 2012 | | | | | | |
| | Plant growth | | Grain yield | | Straw yield | |
| | Method of application | | | | | |
| | Broadcasting | Bedding | Broadcasting | Bedding | Broadcasting | Bedding |
| TSP | 18.8 | 24.2 | 1250 | 1049 | 3242 | 3301 |
| NPK | 21.8 | 27.8 | 1317 | 1407 | 3652 | 3867 |
| DAP | 23.9 | 32.6 | 1496 | 1853 | 3396 | 3830 |
| SE ± | 1.2 | | 131.3 | | 265 | |
| C.V. % | 10.6 | | 19.98 | | 15.11 | |

**Table 4.** Combine analysis for two seasons.

| Method of application | Phosphorus Source | | | | |
|---|---|---|---|---|---|
| | Control | TSP | NPK | DAP | Method main effect |
| Broadcasting | 1369 | 1552 | 1521 | 1812 | 1564 |
| Bedding | | 1664 | 1797 | 2124 | 1738.5 |
| C.V | 13.3 | | | | |
| SE ± | MP =109. | | | | |

MP = interaction

**Table 5:** Partial budget analysis of the effect of methods of application on soybean grain yield (kg/ha) over two seasons2011 &2012

| item | bedding | Broadcasting |
|---|---|---|
| Grain yield(kg/ha) | 1738.5 | 1564 |
| Gross return | 5215.5 | 4692 |
| Variable cost | 238 | 47.6 |
| Net return | 4977.5 | 4644.4 |
| MR | 333.1 | |
| MC | 190.4 | |
| MRR | 174.9 | |

**Table 6:** Partial budget analysis of the effect of different phosphorus fertilizers and broadcasting method of on soybean grain yield (kg/ha) over two seasons2011&2012

| item | control | TSP | NPK | DAP |
|---|---|---|---|---|
| Grain yield(kg/ha) | 1369 | 1552 | 1521 | 1812 |
| Gross return | 4107 | 4656 | 4563 | 5436 |
| Variable cost | 0 | 467.7 | 1719.3 | 523.8 |
| Net return | 4107 | 4188.3 | 2843.7 | 4912.2 |

**Table 7.** Dominance analysis and marginal rate of return

| treatment | Net return | Variable cost | MR | MC | Dominance | MRR % |
|---|---|---|---|---|---|---|
| Control | 4107 | 0 | | | | |
| TSP | 4188.3 | 467.7 | 81.3 | 467.7 | | 17.4 |
| DAP | 4912.2 | 523.8 | 721.2 | 56.1 | | 1285 |
| NPK | 2843.7 | 1719.3 | -2068.5 | 1195.5 | D | |

Treatments were ranked according to the variable cost. "D" stands for dominated treatment and was excluded as a viable treatment according to the economic analysis.

Open American Journal of Agricultural Research
Vol. 2, No. 1, April 2015, pp. 1 - 7
Available online at http://scitecpub.com/Journals.php

**Table 8.** Partial budget analysis of the effect of different phosphorus fertilizers and bedding method on soybean grain yield (kg/ha) over two seasons 2011&2012

| item | control | TSP | NPK | DAP |
|---|---|---|---|---|
| Grain yield(kg/ha) | 1369 | 1664 | 1797 | 2124 |
| Gross return SDG/ha | 4107 | 4992 | 5391 | 6372 |
| Variable cost | | 467.7 | 1719.3 | 523.8 |
| Net return | 4107 | 4524.3 | 3671.7 | 5848.2 |

**Table 9.** Dominance analysis and marginal rate of return

| treatment | Net return | Variable cost | MR | MC | Dominance | MRR % |
|---|---|---|---|---|---|---|
| Control | 4107 | 0 | | | | |
| TSP | 4524.3 | 467.7 | 417.3 | 467.7 | | 89.22 |
| DAP | 5848.2 | 523.8 | 1323.9 | 56.1 | | 2360 |
| NPK | 3671.7 | 1719.3 | -2176.5 | 1195.5 | D | |

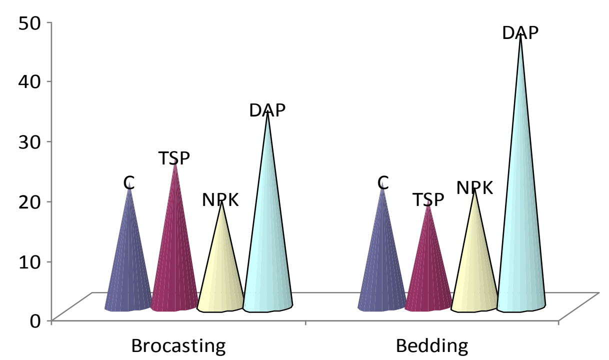
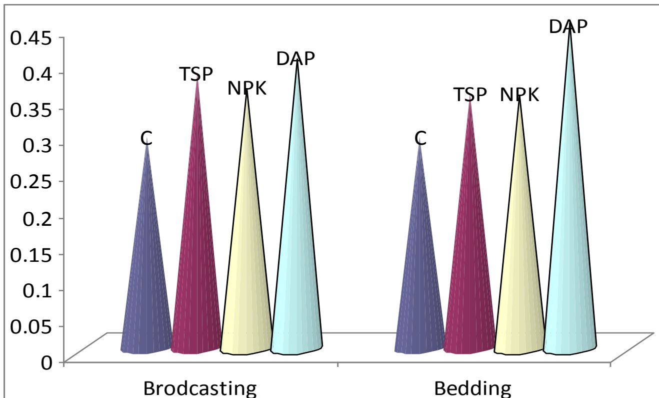



Fig. 1. Effect of different phosphorus sources and different methods of application on soybean nodule number for season 2012




Eig.2. Effect of didderent phosphorus sources and fifferend methods of application on soybean nodule dry weight for season 2012