**AAB BIOFLUX**

**Advances in Agriculture & Botanics-
International Journal of the Bioflux Society**

# Determination of the most limiting mineral nutrient element for growth and development of sunflower (*Helianthus annuus*) in southwestern Nigeria

[1]Babatunde A. Lawal, [2]Gabriel O. Obigbesan, and [2]Ezekiel A. Akinrinde

[1]Department of Agronomy, Ladoke Akintola University of Technology (LAUTECH), PMB 4000, Ogbomoso, Nigeria.
[2]Department of Agronomy, University of Ibadan, Ibadan, Nigeria.
Corresponding author: B. A. Lawal, balawal@lautech.edu.ng; lawalba@gmail.com

**Abstract**. Identifying the most limiting nutrient element among the major nutrient elements (NPK) and its associated deficiency symptoms will go a long way in improving sunflower. Experiments were therefore conducted to identify the most limiting nutrient element and its required rate for optimum production of sunflower. Green house trial using acid washed white sand as growth medium was conducted. There are five treatments (complete nutrient solution, minus N, minus P, minus K, and distilled water) replicated three times, given fifteen treatment units. Fifteen pre-sprouted seeds of sunflower were planted and thinned to 12 plants per pot after one week. K was identified as the most limiting nutrient element. Four levels of K (0, 50, 100, 150 kg $K_2O$/ha) identified in the green house were tried on the field to determine which is the optimum level required for optimum performance of sunflower. Data on agronomic parameters were collected and analysed. The influence of treatments applied has manifested at 2 weeks after planting (WAP) on agronomic parameters taken. The least biomass production and eventual death of sunflower seedlings recorded from plants treated with minus K nutrient solution at 4 WAP pointed to K as the most limiting among the three major nutrient elements (NPK). Highest shoot (198.75 g /plant) and root (42.5 g/plant) yields were produced by minus P and complete nutrient solutions treated plants respectively. The order of limiting is K>N>P. With respect to all agronomic parameters taken on the field, application of K at 100 kg $K_2O$/ha produced significantly higher effects. Highest oil yield (1551.04 L/ha) was also obtained at this level of application but oil content was not influenced by levels of K applied. K was identified as the most limiting nutrient element in sunflower production; it should be applied at 100 kg $K_2O$/ha to produce optimum yield.
**Key Words**: Sunflower, potassium, most limiting nutrient element, deficiency symptom, oil yield.

**Introduction**. Sunflower (*Helianthus annuus* L.) is among the most important annual crops grown for edible oil in the world (Robinson et al 1975). It has wide range of adaptability and it is grown in both developed and developing countries (Khan et al 1999; Jaap et al 1975). Sunflower was never planted in Nigeria before 1965 (Ogunremi 1979ab); but it fits well into Nigeria farming system and could be profitably cultivated both as early and late season crop provided irrigation is available. There has been increased interest in cultivating sunflower as an alternative oil seed crop in Nigeria.

Supply of balanced nutrient combinations cannot be underscore in crop production. Increased nitrogen supply stimulates plant growth and productivity (Joel et al 1997; Lawlor 1995) as well as photosynthetic capacity of leaves (Makino et al 1992). Timing of nitrogen supply as essential as it lays down the primordial for vegetative production, seed formation, and early maturity (Steer et al 1988). In sunflower production, level of leaf N affects rate of photosynthesis (Connor et al 1993); and leaf expansion significantly (Palmer et al 1996). Application of N was reported not to increase oil content in the seed of sunflower while P application did (Raghbir et al 1997). Zhu & Smith (2001) reported that P is the second most limiting nutrient element next to N in agricultural production. P stimulates early root growth and promotes early plant vigour (Verberic et al 2002; Longstreth & Nobel 1980). Zhu & Smith (2001) reported that P is the most important nutrient element limiting agricultural production next to N. They added that improving seed P content may be a useful approach to enhance crop growth under P deficient condition and/or improve the use of P applied to soil; as they observed that plant grown from seeds with high P reserves tended to accumulate more P from soil, which was mainly attributed to better root system development. In sunflower, increase in oil content by P application was reported by Raghbir et al (1997). In line with this was the earlier report that phosphate helped in converting carbohydrate to oil and in carbohydrate metabolism in plant (Samui et al 1987).

Potash is one of the essential elements required for plant growth. Its role is well documented in photosynthesis, enzymatic activity, synthesis of proteins, carbohydrates and fats, translocation of photosynthesis and in enabling the plants to resist pests and disease (Tisdale et al 1985; Navarro 2000; Verberic et al 2002). Also, it plays key role in increasing crop yield and improving the quality of product (Aman & Mushtaq 1999). Sirbu & Ailincai (1992) reported a direct correlation between K application and seed yield of sunflower. This was in agreement with earlier findings of Lewis et al (1991). Contrarily, Ogunremi (1988) had noted that influence of P and K in sunflower production was minimal while that of N was more significant. Comparatively, Aman & Mushtaq (1999) reported that sunflower has very high K requirement. However effect of K on the oil content of sunflower seed was reported somewhat controversial (Lindhauer 1985). Gaur et al (1987) found that application of potassium had no effect on seed oil content of sunflower. On the other hand, Glas et al (1988) reported that K had negative influence on sunflower seed oil content, while Curric (1998) reported that seed oil content were lowest (45.0%) with the highest K application. The need to balance both nitrogen and phosphorus to have good results from K application has been reported by some workers (Osman & Lila 1984; Annaduri et al 1994).

There had been scholarly reports that potassium is essential and required in large quantity by sunflower (Verberic et al 2002; Navarro 2000; Aman & Mushtaq 1999; Malik et al 1989) but it has not been identified as the most limiting nutrient element. Pot experiment was therefore carried out to determine which among the major nutrient elements (NPK) is the most limiting while field trial was carried out to determine optimum requirement of the identified most limiting nutrient element.

## Materials and Methods

**Pot experiment**. Missing nutrient experiment was carried out in the green house with white sand as growth medium. The white sand was collected from river bank in Abraka, Nigeria ($5^0.78^{"}$ N, $6^0.10^{"}$ E), sieved through 2 mm mesh and acid-washed to leach out the nutrients and later with distilled water. To take care of poor water retention ability of sand, method described by Lawal et al (2011) was adopted. A preliminary trial revealed that the wick could not feed the sand beyond 2 kg level; consequently, each pot had 2 kg white sand.

There were five nutrient treatments administered. They are:

i complete nutrient
ii distilled water only
iii complete nutrient minus N
iv complete nutrient minus P
v complete nutrient without K.

The treatments were arranged as CRD replicated three times. The complete nutrient solution was prepared by combining the following quantities of the nutrient carriers per kg white sand; 0.5 g $CaHPO_4$, 0.918 g $Ca(NO_3)_2$, 0.174 g KCl, 0.185 g $MgSO_4$, 4 mg FeEDTA, 20 mg $CuSO_4$, 6 mg $MnSO_4$, 4 mg $CoSO_4$, 5 mg $H_3BO_3$, 5 mg $H_2MoO_4$, 22 mg $ZnSO_4$ (Zhu & Smith 2001).

The missing nutrient solutions were prepared as below:

i without nitrogen (+PK); all combinations above minus $Ca(NO_3)_2$
ii without phosphorus (+NK); all combinations above minus $CaHPO_4$
iii without potassium (+NP); all combinations above minus KCl.

Sunflower seeds (Funtua cultivar) were pre-sprouted on wet filter paper and transplanted on the third day to ensure proper establishment. Fifteen seedlings were transplanted per pot and later thinned to 12 at one week after planting (WAP). The pots had been set up when the pre-sprouting started, to allow the sand absorb enough nutrient solution to sustain plant growth. The agronomic data collected were plant height (cm), number of leaves per plant, dry shoot and root biomass (mg/plant) at 2 and 4 WAP. Biomass harvested were oven dry to a constant weight, ground and taken to laboratory for N, P and K content in shoot and root, and N, P and K uptake (product of percentage content and dry biomass) of shoot and root. All data collected were subjected to analysis of data means were separated using $LSD_{(0.05)}$ Also, the nutrient deficiency symptom(s) observed were recorded.

**Field experiment**. Having established (through green house report) K as the most limiting nutrient element in sunflower growth and development; field trial to determine the optimum level of K required by sunflower was conducted at the Teaching and Research Farm University of Ibadan, Ibadan ($7^0$26'N; $3^0$5'E), Nigeria between August and December, 2006. Four levels of K (0, 50, 100, and 150 kg $K_2O$ /ha) replicated three times were tried. The field was manually cleared; top soil (0-15 cm depth) samples were collected randomly and bulked to form composite for laboratory analysis. The experiment was laid out in randomized complete block design. Each treatment plot measured 4.2 m by 4.2 m with 1 m gap between treatment plots and 2 m between replicates. Planting distance was 0.3 m intra row by 0.6 m inter row. Two to three seeds were planted per hole, and the seedlings were later thinned to one plant per stand at 2 WAP. The treatments were applied at 2 WAP. In addition to this, a basal application of nitrogen (60 kg N/ha using urea) and phosphorus (30 kg P /ha using single super phosphate) was applied to all plots. Weeding was done as required. Heads of sunflower were harvested at 16 WAP when the back of the flower head (capitulum) had changed from green to yellow or brown; this colour change of flower heads indicates readiness for harvest (Weiss 1983). Harvested heads were threshed and winnowed to have the seed separated. Representative seed samples of each treatment were harvested and taken to laboratory for oil content determination using soxhlet extractor. Data collected were subjected to analysis of variance while means were separated using least significant difference at 5%.

## Results

### Response of sunflower seedlings to the missing nutrient element treatment

- *Biomass production*

Analysis of data collected revealed that the treatments applied had significant influence on sunflower plant height ($p \leq 0.01$) and leaf production (Table 1). At 2 WAP, plants subjected to distilled water treatment had the least mean plant height (10.53 cm) which was significantly different from others. The highest mean plant height (17.5 cm) obtained from minus P treated plants was not significantly different compared with 17.17 cm of complete nutrient treated ones. While the plant height from the remaining two treatments treated ones were also not significantly different from each others. However, at 4 WAP, all the plants in the three replicates of minus K nutrient solution treated plant had died. Minus P treated seedlings had the tallest plant (27.3 cm) which was significantly taller than others while those subjected to distilled water treatment had the least height (15.1 cm) was significantly different from others except minus K treated ones which had died. It could be observed that with respect to foliage production, K was most limiting followed by N, while P was least limiting. Dry shoot and root biomass production of the sunflower seedlings were significantly affected by treatment applied ($p \leq 0.05$). Dry shoot biomass obtained at 2 and 4 WAP from minus P treated plants was the highest (117.50 and 198.75 mg per plant stand respectively) but was not significantly different compared with the complete nutrient treated ones at both weeks (Table 2). At 4 WAP, complete nutrient treated plants had the highest root biomass (42.5

mg per plant) which was significantly higher than 32.5 mg per plant obtained from minus P treated ones. The least dry root biomass from distilled water treatment (4.17 mg per plant) was not significantly different compared with that from minus K, 5 mg per plant stand. Ratio of shoot to root biomass (Table 2) revealed that minus K treated sunflower were most affected compared with minus N and P treated ones. Considering the biomass yield, K was the most limiting followed by N. P was not limiting except for root biomass because there was a significant reduction in root production of sunflower treated with minus P nutrient solution compared with complete nutrient treated plants.

Table 1

Effect of missing nutrient elements on plant height and leaf production of young sunflower plants in sand culture

| | Plant height (cm) | | Mean number of leaves /plant | |
|---|---|---|---|---|
| | Weeks after planting | | | |
| Treatment | 2 | 4 | 2 | 4 |
| Distilled water | 10.53 | 15.10 | 4.00 | 4.33 |
| -N | 13.13 | 20.03 | 5.00 | 4.33 |
| -P | 17.53 | 27.30 | 5.67 | 6.67 |
| -K | 12.83 | na | 6.00 | na |
| Complete nutrient | 17.17 | 22.67 | 6.33 | 9.00 |
| $LSD_{(0.05)}$ | 1.70 | 3.29 | 1.35 | 1.66 |

na = Not applicable (the plants has died).

Table 2

Effect of missing nutrient elements on dry biomass (mg /plant) of young sunflower plants in sand culture

| | Dry shoot biomass | | Dry root biomass | Total biomass |
|---|---|---|---|---|
| | Weeks after planting | | | |
| Treatment | 2 | 4 | 4 | 4 |
| Distilled water | 57.50 | 86.25 | 4.17 | 90.42 |
| -N | 67.50 | 93.75 | 20.83 | 114.58 |
| -P | 117.50 | 198.75 | 32.50 | 231.25 |
| -K | 75.00 | 71.25 | 5.00 | 76.25 |
| Complete nutrient | 100.00 | 187.50 | 42.50 | 130.00 |
| $LSD_{(0.05)}$ | 19.00 | 87.88 | 7.50 | 95.38 |

- *N, P, and K contents and uptake*

Data on nutrient content and uptake by the sunflower seedlings was presented on Table 3. N content in the complete nutrient element treated ones was highest (1.83 and 2.03 % dry matter at 2 and 4 WAP respectively). N starved seedlings had the least N content (1.09 %) at 2 WAP while distilled water treated ones had the least at 4 WAP. N content in the seedlings decreased across the treatments at 4 WAP except for complete nutrient treated. The least P content in the shoot of minus P was not significantly different compared with distilled water treated plants at 2 and 4 WAP. Highest values of 0.21 and 0.35 % at 2 and 4 WAP respectively recorded from minus K treated plants were not significantly different from P content obtained from complete nutrient treated plants at both weeks. Also, the K content in the shoot of plants treated with minus K nutrient solution (0.02 % at 2 and 0.10 % at 4 WAP respectively) and distilled water (0.02 % at 2 and 0.03 % at 4 WAP) were not significantly different from each other. Highest K content was obtained from plants treated with minus P solution treated plants at 2 and 4 WAP. It was however not significantly different from K content in shoot of those treated with complete nutrient (Table 3). With respect to nutrient absorbed (uptake), sunflower shoot harvested from those treated with complete nutrient solution had highest N uptake (7.38 and 30.26 mg N /g dry matter at 2 and 4 WAP respectively). At 2 WAP, this value was not significantly different from N uptake by those treated with minus P nutrient solution (5.56 mg N/g dry matter) but was significantly different at 4 WAP (17.44 mg N/g dry matter). N uptakes by those treated with distilled water, minus nitrogen and minus potassium were not significantly different from each other at 2 and 4 WAP (Table 3). P uptake by sunflower plant treated with complete nutrient solution was the highest (0.75 and 3.56 mg P /g dry matter at 2 and 4 WAP respectively). These values were not significantly different compared with P uptake by those fed with minus K nutrient solution. However, those fed with distilled water absorbed least quantity of P. The least value so obtained (0.61 mg P/g dry matter) was not significantly different from values of those treated with minus N (0.93 mg P /g dry matter) and minus P (0.66 mg P /g dry matter). The least quantity of K absorbed in the shoot was recorded from sunflower treated with distilled water at 2 WAP (0.05 mg K /g dry matter) while at 4 WAP, 0.19 mg K /g dry matter was absorbed by those treated with minus K nutrient solution. The highest quantity of K in the shoot was obtained from those treated with minus P nutrient solution, 7.46 and 34.02 mg K /g dry matter at 2 and 4 WAP respectively (Table 3). These highest values were statistically similar compared with K uptake by those treated with complete nutrient solution at 2 WAP (5.10 mg K /g dry matter) and 4 WAP (29.68 mg K /g dry matter).

Table 3

Effect of missing nutrient elements on N, P and K tissue contents (% dry matter) and uptake (mg $g^{-1}$) of young sunflower shoot in sand culture

| Treatment | N | | P | | K | |
|---|---|---|---|---|---|---|
| | Weeks After Planting | | | | | |
| | 2 | 4 | 2 | 4 | 2 | 4 |
| | Nutrient content (% dry matter) | | | | | |
| Distilled water | 1.29 | 0.98 | 0.07 | 0.09 | 0.02 | 0.10 |
| -N | 1.09 | 1.01 | 0.12 | 0.13 | 0.94 | 1.81 |
| -P | 1.19 | 1.12 | 0.06 | 0.04 | 1.56 | 2.26 |
| -K | 1.67 | 1.32 | 0.21 | 0.35 | 0.02 | 0.03 |
| Complete nutrient | 1.83 | 2.03 | 0.19 | 0.24 | 1.26 | 1.98 |
| $LSD_{(0.05)}$ | 0.61 | 0.31 | 0.04 | 0.14 | 0.55 | 0.66 |
| | Nutrient uptake (mg /g dry matter) | | | | | |
| Distilled water | 2.97 | 6.72 | 0.15 | 0.61 | 0.05 | 0.78 |
| -N | 2.86 | 7.43 | 0.32 | 0.93 | 2.49 | 13.43 |
| -P | 5.56 | 17.44 | 0.32 | 0.66 | 7.46 | 34.02 |
| -K | 5.06 | 7.41 | 0.64 | 2.21 | 0.06 | 0.19 |
| Complete nutrient | 7.38 | 30.26 | 0.75 | 3.56 | 5.10 | 29.68 |
| $LSD_{(0.05)}$ | 2.31 | 8.02 | 0.14 | 1.44 | 2.92 | 8.35 |

- *Response of sunflower to levels of K applied on the field*

Potassium application at 100 kg $K_2O$/ha influenced mean plant height significantly compared with other levels of application (Figure 1). The mean number of leaves per plant increased gradually with age till 9 WAP after which senescence set in and the number started reducing. At 6 WAP, sunflower treated with 100 kg $K_2O$/ha produced the highest mean number of leaves (20.67), which was not significantly different from others. Similar trend was observed at other weeks. Except at 7 WAP when the highest mean number of leaves obtained (26.56) from 100 kg $K_2O$/ha treated sunflower was significantly different compared with 24.41 from those treated with 0 kg $K_2O$/ha. K application did not affect leaf production significantly (Figure 2). Analysis of variance of collected data revealed that K level had significant influence on flowering rate from 9 to 11 WAP. At 9 WAP, the highest flowering rate of 3.3 % produced by 50 kg $K_2O$/ha treated plants was not significantly different from 3.2 % by 100 kg $K_2O$/ha but was significantly different from values of other two levels. At 10 and 11 WAP, the least rate of flowering produced by application of 0 kg $K_2O$/ha was significantly different from others, with the highest rate (26.93 % at 10 WAP and 71.16 % at 11 WAP respectively) produced by 100 kg $K_2O$/ha (Figure 3). As from 12 WAP there was no significant difference between the flowering rates produced by each level of potassium.

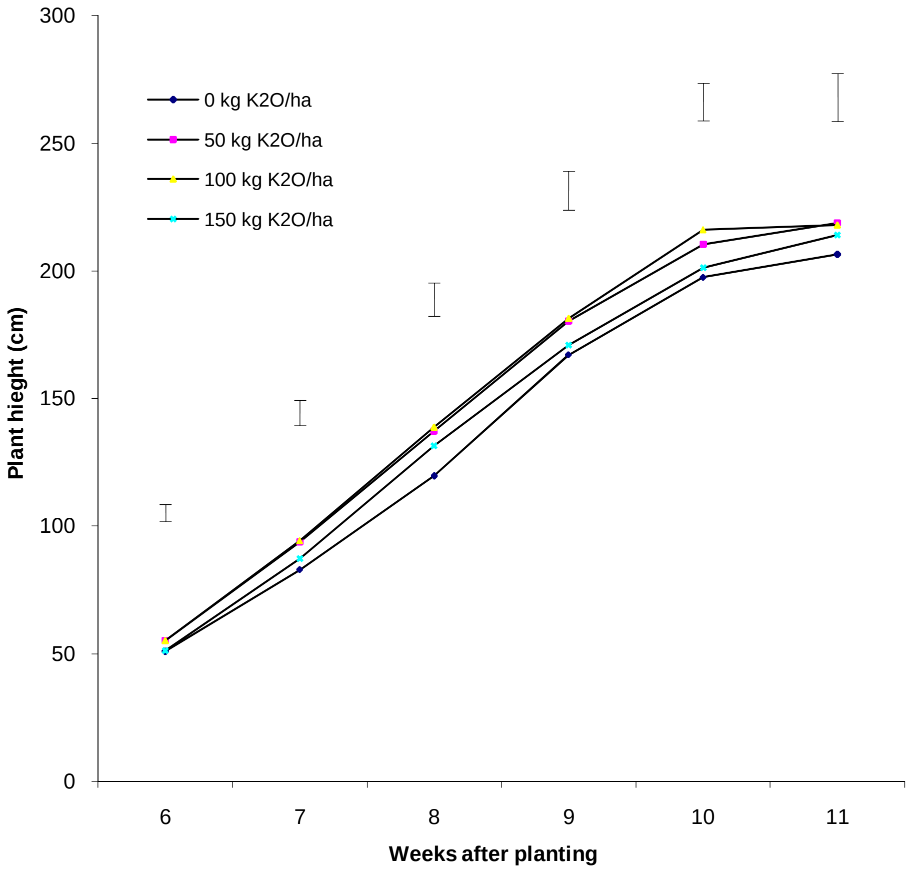


Fig. 1. Influence of levels of potassium on plant height of sunflower (Vertical bars indicate LSD $_{0.05}$).

The influence exerted by level of potassium on sunflower head diameter, head weight and seed yield was significant ($P \leq 0.01$). The highest head diameter (13.14 cm) obtained from sunflower treated with 100 kg $K_2O$/ha was significantly different from values from other levels, with the least (12.25 cm) from the control (0 kg $K_2O$/ha). The highest mean head weight (6046.45 kg/ha) obtained at 100 kg $K_2O$/ha application was significantly different from head weights obtained from other levels of potassium (Table 4). The least head weight of 4738.44 kg/ha from 0 kg $K_2O$/ha was also significantly different from the head weight from the remaining two levels treated plants which were not significantly different from each other. With regards to effect of K on seed yield, the highest quantity (2895.27 kg/ha) obtained from sunflower treated with 100 kg $K_2O$/ha was significantly different from others. There was 28 % reduction between the seed yield at this level of potassium application and the corresponding value (2075.28 kg/ha) obtained from those treated with 50 kg $K_2O$/ha. There was 72 % increase in the seed yield from 100 kg $K_2O$/ha treated sunflower in relation to control treatment (0 kg $K_2O$/ha). Effect of K levels applied on oil yield followed the same trend compared with seed yield.

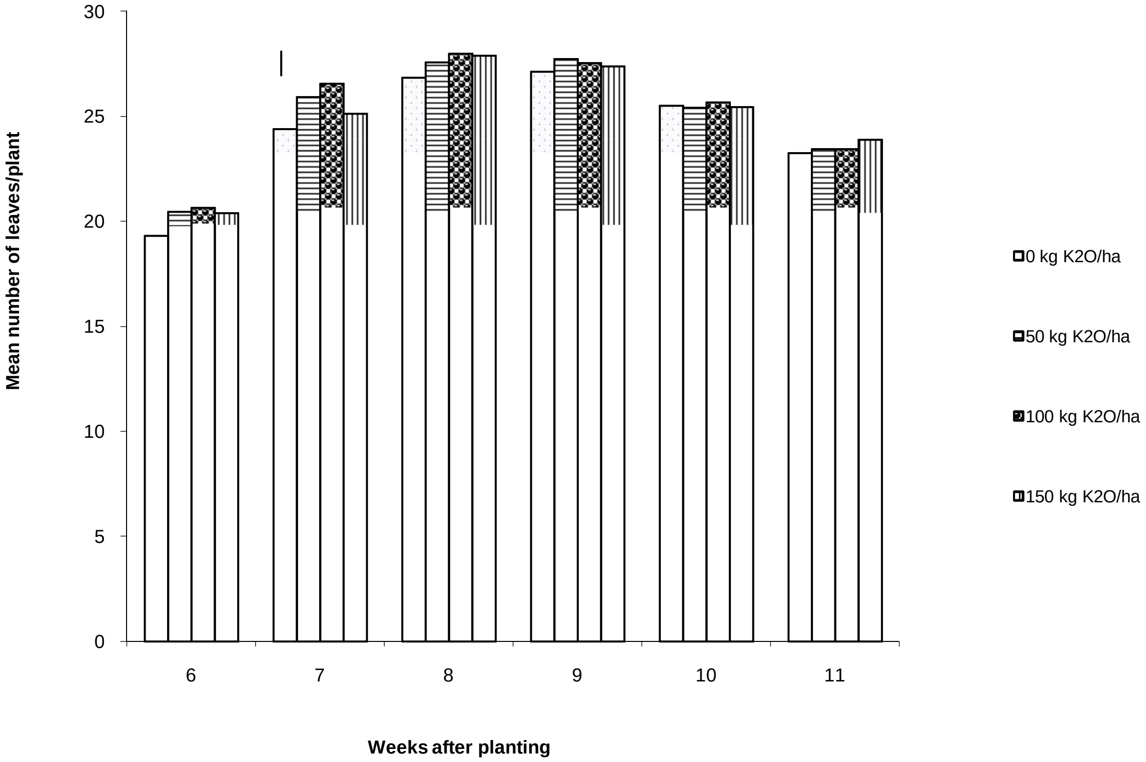


Fig. 2. Influence of levels of potassium on mean number of leaves per plant of sunflower. (Vertical bars indicate LSD $_{0.05}$).

Table 4

Influence of levels of potassium on yield parameters of sunflower

| K level (kg $K_2O$/ha) | Yield parameters | | | |
|---|---|---|---|---|
| | Head diameter (cm) | Head weight (kg/ha) | Seed yield (kg/ha) | Oil yield (L/ha) |
| $K_o$ | 12.35 | 4738.44 | 1679.24 | 899.59 |
| $K_{50}$ | 12.41 | 5009.92 | 2075.28 | 1111.76 |
| $K_{100}$ | 13.14 | 6046.45 | 2895.27 | 1551.04 |
| $K_{150}$ | 12.39 | 5332.39 | 2503.01 | 1340.90 |
| LSD $_{(0.05)}$ | 0.55 | 409.00 | 303.56 | 162.62 |

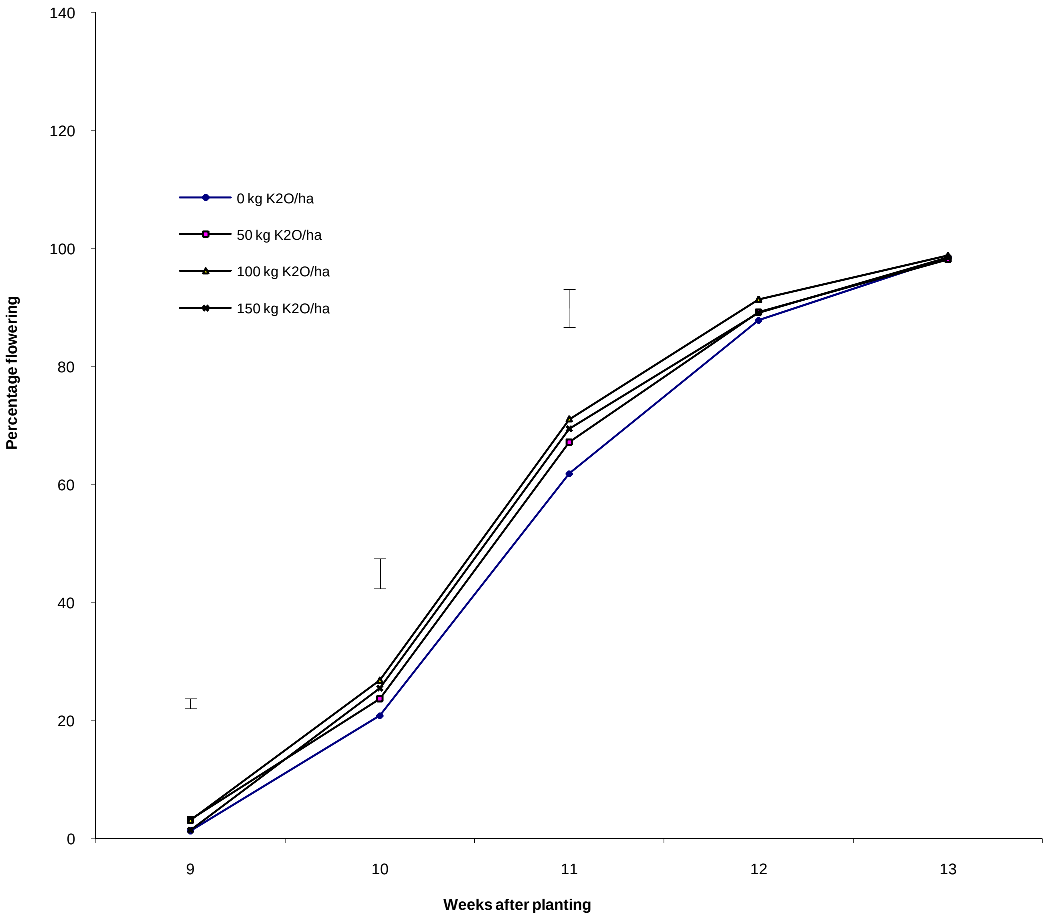


Figure 3. Influence of levels of potassium on percentage flowering of sunflower (Vertical bars indicate LSD $_{0.05}$).

## Discussion

Plants require adequate essential nutrient elements to complete their life cycle (Annaduri et al 1994). Deficiency of any essential nutrient element impacts adversely on plants by causing abnormal growth, failure to complete life cycle, premature senescence or even death. Besides, its role should not be fulfilled by any other nutrient element, while the third measure of essentiality is that the effect of the essential nutrient's deficiency must be direct on some aspect of growth or metabolism. Inadequacy of nitrogen (Lawlor 2002; Joel et al 1997), phosphorus (Zhu & Smith 2001) and potassium (Aman & Mushtaq 1999) had been reported to reduce productivity of sunflower. Washing of the white sand used as the growth medium for the minus nutrient (NPK) experiment in the green house, was to ensure that sunflower planted accessed only nutrients in the planted seeds and supplied nutrient solution. The inclusion of complete nutrient solution was to ascertain the severity of absence of each of the nutrient elements.

The missing nutrient trial showed varied influences on agronomic parameters of sunflower; the most limiting effect was however that of K. Significantly shorter heights and reduced number of leaves recorded from sunflower treated with minus K and followed by minus N nutrient solutions revealed the severity of their deficiency and/or insufficiency especially when compared with the values from minus P treated ones. The similar trends of least shoot and root biomass production by minus K followed by minus N while values obtained from minus P compared favourably with complete nutrient treated sunflower pointed to the fact that K is more limiting in sunflower production compared with N while P is least limiting. The earlier report that sunflower requires high quantity of potassium (Aman & Mushtaq 1999), is an indication that potassium deficiency would reduce the yield of sunflower severely. A likely significant interaction between nitrogen and potassium might account for the better performance of sunflower treated with minus phosphorus (nitrogen and potassium present) nutrient solution. This explained higher nutrient content and uptake by sunflower treated with minus P nutrient solution. With this, potassium could be described as the most limiting nutrient element in sunflower production.

Sunflower plants treated with non-application and/or insufficient supply of K had scorched and frail leaves. It was observed that rainfall distribution during the growing season in 2006 was relatively even except during the first week after planting. This allowed exhibiting full vegetative potentials of the crop; this was in agreement with Hussain et al (1992) and Pandey et al (1984a,b) that water stress at any growth stage impairs physiological process and reduces yields of sunflower. Also, during seed filling stage (October and November), the mean temperature and relative humidity obtained were relatively lower than those of earlier years. Results of laboratory analysis of the soil sampled from the site used for the experiment revealed that nitrogen, phosphorus and potassium were below the critical levels (Uponi & Adeoye 2000). Therefore, the site was suitable to obtain good response to potassium application. This also necessitated basal application of N and P.

The heads harvested on plots where no potassium was applied were generally smaller in size compared with where it was applied. The effect of potassium application on diameter of sunflower heads was not much pronounced but manifested well on head weight, as heads of those without K were lighter. The result from the work is in agreement with the observation of Aman & Mushtaq (1999), that comparatively, sunflower has high potash requirement. The optimum K application of 100 kg $K_2O$/ha, in this work, significantly increased seed yield (72 %) relative to where there was no K application, likewise other yield parameters. This result emphasized the vital role of K in sunflower seed production.

Potassium was found not to influence oil content of sunflower seed significantly. Similar observation about influence of potassium on oil content of sunflower seed had been noted by Gaur et al (1987). Conversely, Glas et al (1988) had reported a negative influence of potassium application on oil content of sunflower while Ahmad (1993); Nazir et al (1987) observed increase in oil content of sunflower due to potassium application. These contradictory reports might have been due to differences in fertility status of soil or genetic makeup of the crop (Ayub et al 1999).

## References


Ahmad R., 1993 Physio-agronomic characteristics of semi-dwarf and standard height sunflower hybrids as affected by nutritional area and potassium application. Ph. D. Thesis. University of Agriculture, Faisalabad, Pakistan.

Aman U. C., Mushtaq M., 1999 Optimization of potassium in sunflower. Pakistan Journal of Biological Science **2**(3):887–888.

Annaduri K., Seshadri P., Palaniappan S., 1994 Influence of potassium levels on yield and oil content in sunflower soybean sequence. Journal Potassium Research **10**:124-129.

Ayub M., Tanveer A., Amin M. Z., Sharar M. S., Pervaiz A., 1999 Effect of different sources and levels of potash on yield and oil content of spring sunflower. Pakistan Journal of Biological Science **2**(3):801-803

Connor D. J., Hall A. J., Sadras V. O., 1993 Effect of nitrogen content on the photosynthetic characteristics of sunflower leaves. Australia Journal Plant Physiology **20**:251-263.

Curric R., 1988 Contribution to the study of the effect of applying nitrogen, phosphorus, and potassium fertilizers to sunflower in stationary experiments on yield, chemical composition, and nutrient removal. Archiv Za Polfoprivredne Nauke **49**:107-121.

Gaur S. L., Bangar A. R., Kadam S. K., 1987 Effect of graded doses of nitrogen, phosphorus and potassium on the yield and oil contents of sunflower. Current Research Reporter, Mahatma Phule Agricultural University **3**:77-81.

Glas K., Kali I., Kassel A. G., 1988 Fertilizing for high yield and quality sunflower. IPI Bulletin No. 107 International Potash Institute, Switzerland.

Hussain N. M., Chaudhry M. S., Malik, S. M., Nasir, M., 1992 Proceedings of 33rd symposium. Soil Science Society of Pakistan.

Jaap J. L., Van Waalwijk A., Van Doorn B., 1975 Sunflower role in developing countries. Sunflower Newsletter **2**(4):5-7.

Joel G., Gamon J. A., Field C. B., 1997 Production efficiency in sunflower. The role of water and nitrogen stress. Remote Sensing of the Environment **62**:176-188.

Khan M. A., Ahmad K., Ahmad J., 1999 Effect of potassium levels on the yield of sunflower (*Helianthus annuus* L.). Pakistan Journal of Biological Science **2**(2):402-403.

Lawal B. A., Obigbesan G. O., Akinrinde E. A., 2011 Effects of rates and methods of boron (B) application on sunflower (*Helianthus annuus* L.) productivity. Research on crops Journal **12**(3). (In press)

Lawlor D. W., 1995 Photosynthesis, productivity, and environment. Journal of Experimental Botany **46**:1449-1461.

Lawlor D. W., 2002 Carbon and nitrogen assimilation in relation to yield: mechanisms are the key to understanding production systems. Journal of Experimental Botany **53**: 773-787.

Lewis D. C., Potter T. D., Weckert S. E., 1991 The effect of N, P and K fertilizer applications on the seed yields of sunflower grown on sandy soil and the prediction of P and K responses by soil test. Fertilizer Research **28**:185-190.

Lindhauer M. G., 1985 Influence of K nutritional drought on water relations and growth of sunflower (*Helianthus annuus* L.) Z. Pflanzenernaehr Bodenk **148**:654-669.

Longstreth D. J., Nobel P. S., 1980 Nutrient influences on leaf photosynthesis. Effects of nitrogen, phosphorus, and potassium for *Gossypium hirsutum* L. Plant Physiology **65**(3):541-543.

Makino A., Sakashita H., Hidema J., Mae T., Ojima K., Osmond B., 1992 Distinctive responses of ribulose-1,5-bisphosphate carboxylase and carbonic anhydrase in wheat leaves to nitrogen nutrition and their possible relationships to $C0_2$ transfer resistance. Plant Physiology **100**:1737-1743.

Malik S. M., Chaudhry R. A., Hussain G., 1989 Crop response to potassium application in the Punjab. In: Proceeding Workshop on 'Role of potash in improving fertilizer use efficiency'. March 21-22, 1989 UDFC/PARC, Islamabad, Pakistan.

Navarro G., 2000 Quimica Agricola. Editorial Mundi-Prensa, Madrid, Espana, pp 219-231 (ISBN 84-7114-905-2).

Nazir M. S., Maqsood M., Ahmad R., Yasin M., 1987 Growth, yield and oil content of spring sunflower as influenced by NPK fertilizer application. Pakistan Journal of Science and Industrial Research **30**:142-145.

Ogunremi E. A., 1979a Preliminary trials on sunflower performance in southwestern Nigeria. Vegetable for the Hot Humid Tropics **4**:40-42.

Ogunremi E. A., 1979b Effect of sowing date on sunflower performance in southwestern Nigeria. The Sunflower International Newsletter **3**(4):15-19.

Ogunremi E. A., 1988 Sunflower in Nigeria from planting to processing. Institute of Agricultural Research and Training, Research Bulletin No. 17.

Osman R. O., Lila B. H. A., 1984 Effect of levels of nitrogen, phosphorus and potassium on some agronomic characters and seed oil composition of sunflower. Zeitschrift fur Acker-und Planzenbau **153**:241-245.

Palmer S. J., Brridge D. M., MacDonald A. J. S., Devies W. J., 1996 Control of leaf expansion of sunflower (*Helianthus annuus* L.) by nitrogen nutrition. Journal Experimental Botany **47**:359-368.

Pandey R. K., Herrera W. A. T., Pendleton J. W., 1984a Water stress response to grain legumes under irrigated gradient III. Plant growth. Agronomy Journal **76**:557-560.

Pandey R. K., Herrera W. A. T., Pendleton J. W., 1984b Water stress response to grain legumes under irrigated gradient. I. Yield and yield components. Agronomy Journal **76**:549-553.

Raghbir S., Sharma R. K., Mohinder S., 1997 Studies on soil potassium and response of sunflower to applied potassium on some soils of Haryaria. Journal of Indian Society of Soil Science **45**(2):301-305.

Robinson R. G., Troneme S., Boniface R., 1975 Observations on the application of phosphorus-potassium fertilizer to sunflower. C.E.T.I.D.M. Introduction Techn **47**: 29-37.

Samui R. C., Bhattaharyya P., Roy A., 1987 Effect of nutrient and spacing on oil yield and uptake of nutrient by Khaiif Sunflower. Journal of Indian Society of Soil Science **35**(1):69-73.

Sirbu M., Allincai D., 1992 The effect of long-term fertilizer applications including NPK on the grain yields and quality of sunflowers. Cercetari Agronomice in Moldova **25**: 181-187.

Steer B. T., Hocking P. J., Low A., 1988 Dry matter, minerals and carbohydrates in the capitulum of sunflower (*Helianthus annuus* L.): Effect of competition between seeds and defoliation. Field Crops Research **18**:71-85.

Tisdale L. S., Nelson W. L., Beaton J. D., 1985 Soil Fertility and Fertilizers ($4^{th}$ Ed.). Macmillan Pub. Co., New York.

Uponi J. I., Adeoye G. O., 2000 Soil Testing and Plant Analysis: an overview. In: Agronomy in Nigeria. Compiled and Design by M.O. Akoroda.

Verberic R., Stampar F., Vodnik D., 2002 Influence of the foliar application of phosphorus and potassium on the photosynthetic intensity in apple tress (*Malus domestica* Borkh). Acta Horticulturae **549**:165-170.

Weiss E. A., 1983 Sunflower in oil seed crops. Longman Publication, 402-462.

Zhu Y. G., Smith S. E., 2001 Seed phosphorus (P) content affects growth, and P uptake of wheat plants and their association with arbuscular mycorrhizal (AM) fungi. Plant and Soil **231**:105-112.

Received: 06 July 2011. Accepted: 15 July 2011. Published online: 22 July 2011.

Authors:
Babatunde Akeem Lawal, Department of Agronomy, Ladoke Akintola University of Technology (LAUTECH), PMB 4000, Ogbomoso, Nigeria; e-mail: balawal@lautech.edu.ng; lawalba@gmail.com
Gabriel Olufemi Obigbesan, Department of Agronomy, University of Ibadan, Ibadan, Nigeria; e-mail: wafemiobi@yahoo.com
Ezekiel Akinkunmi Akinrinde, Department of Agronomy, University of Ibadan, Ibadan, Nigeria; e-mail: akinakinrinde@yahoo.com

How to cite this article:
Lawal B. A., Obigbesan G. O., Akinrinde E. A., 2011 Determination of the most limiting mineral nutrient element for growth and development of sunflower (*Helianthus annuus*) in southwestern Nigeria. AAB Bioflux **3**(2):93-103.