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Influence of Humic Acid and Potassium on the Growth and Yield of Squash (*Praecitrullus fistulosus* L.)

[1]Nadeem Khan, [1]Abdul Mateen Khattak, [1]Syed Tanveer Shah and [2]Asif Iqbal

[1]Department of Horticulture, Faculty of Crop Production Sciences,
The University of Agriculture Peshawar-25130, Pakistan
[2]State Key Laboratory of Cotton Biology, Cotton Research Institute,
Chinese Academy of Agricultural Sciences, Anyang, China

Abstract: A research study "influence of humic acid and potassium on the growth and yield of squash" was conducted in the Agricultural Research Station Swabi, during 2016. Three humic acid levels (0, 10 and 20 kg ha^{-1}) and five potassium levels (0, 30, 60, 90 and 120 kg ha^{-1}) were used in the experiment. The experiment was laid out in randomized complete block design with two factors. Various growth and yield parameters were studied including number of leaves, leaf area (LA)$plant^{-1}$, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), absolute growth rate (AGR), single fruit weight, number of fruits and yield. In case of different humic acid levels maximum number of leaves $plant^{-1}$ (12.4), LA (1970.4 cm^2), LAI (1.2), CGR (12.6), NAR (1.4), AGR (2), fruit weight (63.6 g), number of fruits $plant^{-1}$ (10.8) and yield (17.5 t ha^{-1}) were recorded in 20 kg HA ha^{-1}. In case of different potassium levels more number of leaves $plant^{-1}$ (12.3), LA (2028.7 cm^2), LAI (1.3), CGR (12.6), NAR (1.4), AGR (2), fruit weight (60.4 g), number of fruits $plant^{-1}$ (10.3) and yield (17.6 t ha^{-1}) were recorded in 90 kg K ha^{-1}. Significant interactions between humic acid and potassium levels were observed. On the bases of conclusion obtained it is recommended that both humic acid (20 kg ha^{-1}) and potassium (90 kg ha^{-1}) for better growth and yield of squash.

Key words: Squash・Humic Acid・Potassium Fertilizer・Growth・Yield

INTRODUCTION

Squash (*Praecitrullus fistulosus* L.) is the most important crop of family Cucurbitaceae. It is a highly polymorphic vegetable [1] grown during warm season in tropical and subtropical environments. In Pakistan it is cultivated on an area of 10494 hectares with a production of 97166 tons, while in Khyber Pakhtunkhwa it is grown on about 1120 hectares area with a total production of 12833 tons [2].

Humic acid is used as one of organic-mineral fertilizers. It is also used for supplementing chemical fertilizers that reduce cost of production without compromising on yield. It is commercial products containing several elements that improve soil fertility and increase the availability of nutrients thus increase plant growth and yield. It particularly is used to ameliorate or reduce the negative effect of salt stress [3]. During the process of humification of organic materials, humic substances are formed as by-product of microbial metabolism. Depending upon the origin, molecular size, chemical characteristics and concentration, humic substances are caught up in a range of different metabolic effects on plant [4]. The beneficial effects of humic substances on plant growth is related to their indirect (enhancing fertilizer efficiency or reducing soil compaction), or direct (progress of the overall plant biomass) effects [5]. Also, humic substances increase the growth rate by stimulating enzyme activities [6, 7]. Humic acid is extracted from different sources such as soil, humus, peat, oxidized lignite and coal. Humic acid has positive effect on the growth of shoots and roots, absorption of macro nutrients (N, K, Ca, Mg and P) by plant. Humic acid is reliable with nature and is not dangerous for the plant and environment [8]. Abdel-Mawgoud *et al.* [9] states that humic acid

Corresponding Author: Nadeem Khan, Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture Peshawar-25130, Pakistan.

increases plant growth through chelating different nutrients to overcome the deficiency of nutrients and being equipped with hormonal compounds, has beneficial effects on growth, production, quality of agricultural commodities and increases photosynthetic activity and leaf area index [10].

Potassium (K) is very important plant nutrient that helps in internal reactions of the plant and improve quality of the crop. The key role of K is to activate several enzymes in plant that act as catalysts for making materials such as starch and protein. It also plays a vital role in photosynthesis, osmotic adjustment, cell growth, stomatal regulation, water system of plant, downloading carbohydrates made in the leaves into phloem, transporting them within the plant, anion-cation balance and as accompanying cation in nitrogen transfer [11]. Squash needs potassium in early plant stages for better growth and development. According to Buwalda and Freeman [12], supply of nutrients during early growth stages is very important. The second side-dressing of potassium, which some farmers apply at later stages of plant growth, is too late to be beneficial for the crop. On the other hand, Swiader *et al*. [13] found that potassium application at alter stages resulted in smaller fruit production. Buwalda and Freeman [12] reported that potassium at higher levels increases the number of fruits per plant. Potassium is a drought resistant nutrient that helps save the plants from abiotic stresses such as frost, aridity, airless soil conditions, salinity and sodicity and biotic factors, such as diseases. Therefore, plants with ample supply of potassium during growth can produce good yields and quality even under stressed conditions [14]. Keeping in view the importance of potassium and humic acid, the present experiment was designed to observe the effect of humic acid, potassium levels and their interaction on growth and yield of squash.

MATERIALS AND METHODS

The proposed research study entitled "Influence of humic acid and potassium on the growth and yield of squash" was conducted at Agricultural Research Station Swabi during the year 2016. The experiment was conducted in Randomized Complete Block Design (RCBD) with two factors humic acid (0, 10 and 20 kg ha^{-1}) and potassium (0, 30, 60, 90 and 120 kg ha^{-1}), replicated three times. Row to row distance was kept 90 cm and plant to plant distance 25 cm. The plot size was 5.4 m^2 each with three rows. Squash Cv. Indian gooltinda was used as study material. Sowing was done on 15 March 2016. The emergence (50%) took about 10 days.

Treatments Application: The composition of humic acid that contain (C 50%, O_2 40%, H 5%, N 3%, P <1% and S <1%). Humic acid was applied to the soil at seed bed preparation. Potassium in the form of sulphate of potash (SOP) was used and applied before sowing at seed bed preparation.

Statistical Analysis: The data collected during experiment were analyzed statistically using two factors ANOVA technique and in case of significant differences, the treatments means were compared using LSD-test [15].

Data Were Recorded on the Following Variables During the Course of Study: Number of the leaves plant^{-1} was counted from five randomly selected plants from each plot and average was calculated. Leaf area (cm^2) plant^{-1}of whole plant was calculated by using leaf area meter from randomly selected 3 plants and then mean obtained. Leaf area index was obtained by the ratio of leaf area of single plant to the area of the land it had occupied.

Leaf area index = LA / Area per plant

CGR is growth in gram per unit area per unit time. One plant cut 15 days (T1) after germination and then dry to weight (W1), another plant cut 30 days (T2) after germination and dry to weight (W2). Measure the ground area of a single plant. Weight 1 subtracted from weight 2 divide by time 1 subtracted from time 2 and then multiplies 1 divide by one plant ground area, using the following formula:

$$\text{CGR} = \frac{w_2 - w_1}{T_2 - T_1} x \frac{1}{Ground\ Area}$$

Crop growth rate is expressed in grams per meter square per day (g m^{-2} day^{-1}).

NAR is assimilate producing by leaves for plant in gram per unit area per unit time. First calculate crop growth rate, then leaf area per plant two times that the plant cuts at two stages for absolute growth and crop growth rate.

Net assimilation rate was calculated using the equation.

$$\text{NAR} = CGR\ x \frac{\ln LAI2 - \ln LAI1}{(LAI2 - LAI1)}$$

Absolute growth rate is the growth per unit time. One plant cut 15 days (T1) after germination and then dry to weight (W1), another plant cut 30 days (T2) after germination and dry to weight (W2). W1 subtracted from W2 divide by T1 subtracted from T2.

$$AGR = \frac{w_2 - w_1}{T_2 - T_1}$$

Single squash fruit weight (g) was measured with the help of electric balance by weighing three randomly selected plants fruits from each plot for all treatments in each replication and the average was calculated. Number of fruits plant^{-1} wastaken by counting the fruits picked from three randomly selected plants and then the average was calculated.Fruits yield was calculated from each plot then divide by plot area and multiplied by 10000 and then divided by 1000 to convert from kg to tons, through the following formula.

$$Yield\ (tons\ ha^{-1}) = (\frac{Yield\ per\ plot}{Area\ per\ plot} \times 10000) / 1000$$

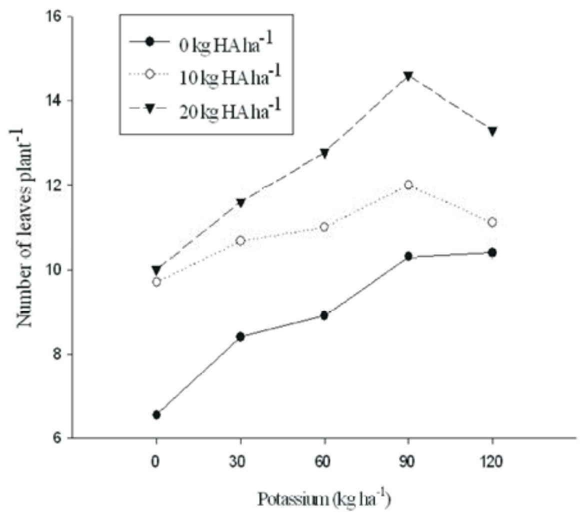

Fig. 1: Interactive effect of humic acid and potassium on number of leaves plnat^{-1}

RESULTS AND DISCUSSION

The results regarding growth and yield parameters of squash as influenced by humic acid and potassium levels are presented in the following lines.

Number of Leaves Plant^{-1}: Data pertaining to the number of leaves plant^{-1} of squash was significantly ($P \leq 0.001$) affected by the application of humic acid and potassium rates. However, the interaction between HA and K was also found significant ($P \leq 0.05$), as shown in Figure 1. The mean value for interaction (Figure 1) also followed a similar as those of plant height interaction. The number of leaves at different HA levels increased with the increase in K dose upto 90 kg ha^{-1}, but then declined above this level. However, the decline was steady at all the HA levels unlike plant height. It was also observed that the application of HA increased the leaf number even without the use of K. Greater number of leaves is due to humicacid application to the soil is due to the increasedavailabilityof major nutrient potassium to the plants. These results are in accordance with the findings of Baldotto and Baldotto [16], who reported greater number of leaves due to improvement of potassium uptake and reduction in water evaporation from soils. Sober *et al*. [17] reported that the application of potassium at sowing time increased enzymes activation which increased number of leaves and average leaf area. Eltilib *et al*. [18] reported that HA and potassium application significantly increased number of leaves of okra compared to the control.

Leaf Area (cm^2) Plant^{-1} and Leaf Area Index (LAI): Data pertaining toleaf area (LA) plant^{-1}and LAI were significantly ($P<0.001$) affected by the application of humic acid and potassium rates (Table 2), while the interaction was found non-significant.Mean values of LA and LAI for different humic acid doses indicated that maximum LA (1970.4 cm^2) plant^{-1} and LAI (1.2) were recorded in plants treated with 20 kg HA ha^{-1}, whereas minimum LA (1353.8 cm^2) plant^{-1} and LAI (0.8) was observed in plants that received no HA.The application of potassium at 90 kg ha^{-1}gave maximum (2028.7 cm^2) LA plant^{-1} and LAI (1.3), whereas the lowest LA (1323.5 cm^2) and LAI (0.8) was recorded for plants grown in plots that received no K. The increase in average leaf area and LAI of squash might be due to the increase in the activation of enzymes due to the highest level of potassium availability byhumic acid application. The availability of potassium for longer period of time to the plant might be responsible for increasing photosynthetic activity, which in turn increased leaf area. Valdrighi *et al*. [19] reported that enhancement in the growth of tomato (*Solanum lycopersicum* L.) and cucumber leaves may be possible because of incorporation of HA into soil which increases nutrients uptake by the plants for increasing photosynthetic activity, which in turn increasesleaf area. Albayrak and Camas [20] stated that that humic acid increases plant growth through chelating different nutrients to overcome the lack of nutrients and has useful effects on growth, production and quality of agricultural produce. Haghigh *et al*. [8] and Ghorbani *et al*. [10] stated that humic acid has remarkable effects on leaf area index. Potassium also increased leaf area index in comparison to other treatments. Lack of potassium, due to shortage in the soil and non-availability to plant due to drought

Table 2: Leaf area (cm^2), leaf area index and single fruit weight (g) as influence by humic acid and potassium levels

Humic acid (HA) kg ha^{-1}	Leaf area (cm^2)	Leaf area index	Single fruit weight (g)
0	1353.78 c	0.85 c	54.96 b
10	1707.59 b	1.07 b	55.68 b
20	1970.44 a	1.23 a	63.58 a
$LSD_{(0.05)}$	131.9	0.08	1.66
Potassium (K) kg ha^{-1}			
0	1323.48 e	0.83 d	53.93 b
30	1538.14 d	0.96 c	58.41 a
60	1679.44 c	1.05 c	58.44 a
90	2028.65 a	1.27 a	60.35 a
120	1816.65 b	1.14 b	59.22 a
$LSD_{(0.05)}$	170.3	0.10	2.14
HA x K			
$LSD_{(0.05)}$	Ns	Ns	Ns

Means followed by similar letters are statistically non-significant at 5 % level of significance

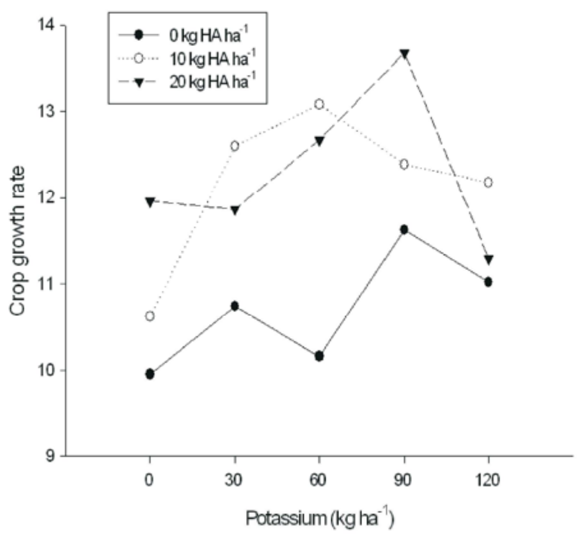

Fig. 2: Interactive effect of humic acid and potassium on crop growth rate

affected leaf expansion and dramatically reduced carbon exchange rate. The increase of leaf area index with increased potassium application could be the result of improved root system and more access to necessary plant nutrients. Moreover, potassium has a very important role in photosynthesis, cell division, growth and water economy for the plant [17]. Azizi [21] reported that consumption of potassium oxide would improve leaf area index.

Crop Growth Rate (CGR) (gm^{-2} day^{-1}): Data pertaining to the crop growth rate (g m^{-2} day^{-1}) wassignificantly ($P<0.001$) affected by the application of humic acid and potassium. However, the interaction between HA andK interaction was also significant ($P<0.05$), as shown in Figure 4. Interaction between humic acid and potassium levels (Figure 2) indicates that the application of 20 kg HA ha^{-1} with different K doses increased the crop growth rate to maximum of 13.7 g m^{-2} day^{-1} at 90 kg K ha^{-1} dose, but then declined above this dose, such that plants receiving 120 kg K ha^{-1} attained a crop growth rate of 11.3g m^{-1} day^{-1}. However, a different trend was seen with the other HA treatments. At 10 kg HA ha^{-1}dose, the CGR increased with K dose to a maximum of 13.1 g m^{-1} day^{-1} at 60 kg K ha^{-1}dose but then declined when K dose was further increased to 90 and 120 kg K ha^{-1}. The CGR response to K doses without the use of HA was haphazard. The CGR increased from 0 to 30 kg K ha^{-1} dose and decreased at 60 kg K ha^{-1} but then increased at 90 kg K ha^{-1} and declined again at 120 kg K ha^{-1}. In the treatment with application of 90 kg ha^{-1} potassium fertilizer and 20 kg ha^{-1} humic acid, crop growth rate was more than the other treatments and increasing trend of crop growth rate was observed. This trend is due to gradual increase of absorbing solar radiation together with increase of green cover percentage at the beginning of growth season and consequently the increase of dry matter accumulation in plants. As it is observed in other treatments when the leaves get old and the rate of dry mater accumulation decreases crop growth rate decreases, too. The decrease of crop growth rate at final stages could be due to decrease of plant dry matter because of the fall of leaves. Generally, crop growth rate depends on canopy photosynthesis per area unit of land. The results of this part are consistent with the findings of Haghighi *et al.* [8] and Daur and Bakhashwain [22], as the increase of humic acid increased crop growth. Potassium consumption has increased crop growth rate in comparison to control treatment, which is consistent with the findings of Azizi [21] and Beik-Nejad [23]. They reported that potassium consumption increased CGR in comparison to control treatment.

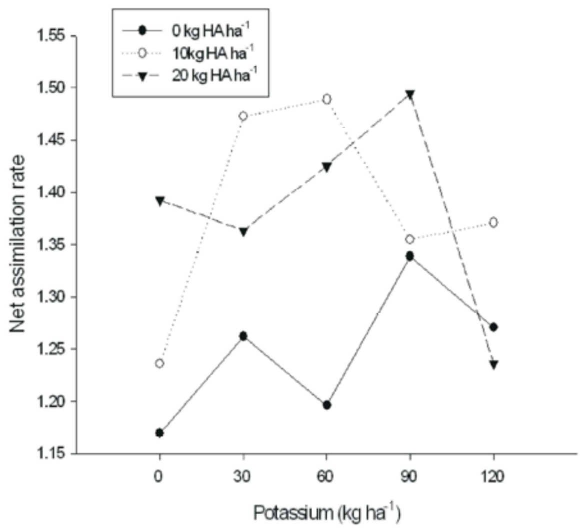

Fig. 3: Interactive effect of humic acid and potassium on net assimilation rate

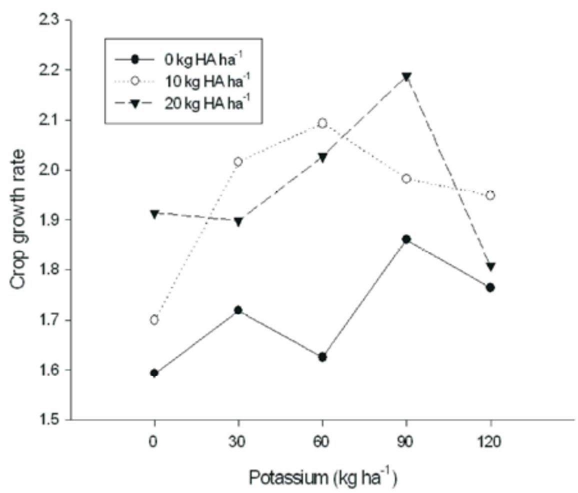

Fig. 4: Interactive effect of humic acid and potassium on absolute growth rate

Net Assimilation Rate (NAR): Data on NAR wassignificantly ($P<0.001$) affected by the application of humic acid and potassium rates. However, the interaction between HA and K was also found significant ($P<0.05$), as shown in Figure 5. Interaction between humic acid and potassium levels (Figure 3) indicates that the application of 20 kg HA ha^{-1} with different K doses increased the net assimilation rate to maximum of 1.5 at 90 kg K ha^{-1} dose, but then declined drastically above this dose, such that plants receiving 120 kg K ha^{-1} attained a net assimilation rate of 1.2. In case of 10 kg HA ha^{-1}, the net assimilation rate increased upto 60 kg K ha^{-1} (1.49) but then decreased to 1.35 at 90 kg K ha^{-1} and slightly increased to 1.37 at 120 kg K ha^{-1} dose. The plants that did not receive any HA treatment followed a similar as those of CGR in response to K doses.After planting the net assimilation rate of crop increases, but the increase was similar at different levels of potassium and humic acid, but still the highest NAR was recorded from 90 kg K ha^{-1} and 20 kg HA ha^{-1}. It further showed that like other growth parameters NAR also shows similar response to potassium and humic acid. El-hendi *et al*. [24] showed that as the plant gets older, NAR decreases due to leaves aging and their shadows on each other decrease of active photosynthesis area. When all leaves are exposed to sunlight completely, NAR is maximized. Azizi [21] reported that high levels of potassium in soil lead to the highest NAR, which might be due to stimulation and formation of photosynthetic activity with the application of potassium.

Absolute Growth Rate (AGR): Data regarding to the AGR was significantly ($P<0.001$) affected by the application of humic acid and potassium rates. The interaction between HA andK was also found significant ($P<0.05$), as shown in (Figure 4). The mean values of interaction between humic acid and potassium levels (Figure 6) indicate that the application of 20 kg HA ha^{-1} with different K doses increased the absolute growth rate to maximum of 2.19 at 90 kg K ha^{-1} dose, but then declined sharply abovethis dose, such that plant receiving 120 kg K ha^{-1} produced absolute growth rate of 1.81. In case of 10 kg HA ha^{-1} dose, the absolute growth rate increased to 2.09 at 60 kg K ha^{-1} dose but declined at 90 and 120 kg K ha^{-1} dose. At different growth stages, total dry weight of plant has increased. The total dry weight of plants in 20 kg ha^{-1} humic acid treatmentwas more than thoseof other treatments. This shows that as humic acid increases, total dry weight increases, too. The results obtained in this section are consistent with the findings of Haghighi *et al*. [8]. Turkmen *et al*. [25] stated that humic acid could sustain photosynthetic tissues andthus total dry weight would increase. Lack of access to soil potassium supply particularly at sensitive stages of reproductive growth has led to production and transfer of less photosynthetic material and reduction of dry weight at zero level of potassium. All levels of potassium fertilizer and humic acid, maximized dry matter accumulation 30 days after plant emergence. The plant transferred its accumulated dry matter into reproductive organs and the loss of leaves led to decrease of dry matter accumulation. The lowest dry matter was observed in control treatments due to lack of consumption of potassium and humic acid. Majedi and Khademi [26] showed that application of potassium had a key role in increasing the absolute growth rate. The results were consistent with the findings of Azizi [21].

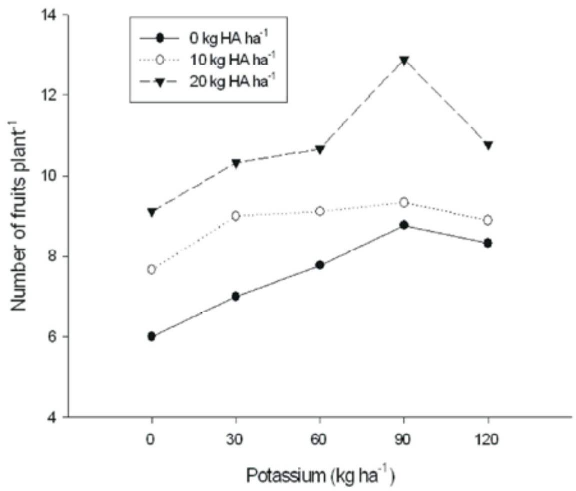

Fig. 5: Interactive effect of humic acid and potassium on number of fruits plant^{-1}

Single Fruit Weight (g): Data regarding to the single fruit weight (g) of squash was significantly (P<0.001) affected by the application of humic acid and potassium rates (Table 2). The interaction betweenHA and K was found non-significant. Mean value of single fruit weight for different humic acid doses indicate that maximum fruit weight (63.6 g) wasrecorded in plants treated with 20 kg HA ha^{-1}, whereas minimumfruit weight (55 g) was observed in plants that received no HA. The application of potassium at the rate of 90 kg ha^{-1} produced maximum fruit weight (60.4 g), but it was also at par with other K doses i.e 30, 60 and 120 kg K ha^{-1}, Whereas the lowest fruit weight (53.9 g) was observed in plants grown in plots that received no K.Fruit weight was higher with the application of K fertilizer, because it increased dry matter accumulation in leaves, which ultimately increased plant growth and fruit production. Increase in fruit weight of pumpkin with the increase in potassium fertilizer as also reported by Al-Mukhtar *et al*. [27]. Similarly, Solaiman *et al*. [28] stated that higher fruit weight and other plant growth parameters in pumpkin were positively affected bythe application of potassium. Khan *et al*. [29], alsoachievedmaximum fruit weight in plots treated with HA. The results are in line with Atak and Kaya [30], who reportedincrease in fruit weight of cucumber and pumpkin by HA soil application as compared to control treatment. Thenmozhi *et al*. [31] also reported heavier fruit weight in groundnut with soil HA application at the rate 20 kg ha^{-1}.

Number of Fruits Plant^{-1}: Data recorded to the number of fruits plant^{-1} of squash was significantly (P<0.001) affected by the application humic acid and potassium rates. However, the interaction between HA and K was also significant (P<0.05), as shown in figure 5.The Interaction between humic acid and potassium levels (Figure 5) indicates that the application of 20 kg HA ha^{-1} with different K doses increased the fruits weight to maximum of 12.9gm at 90 kg K ha^{-1} dose, but then declined sharply above this dose, such that plants receiving 120 kg K ha^{-1} attained a weight of 10.8gm. Significant increased in the fruits number might be due to increase in water and nutrient holding capacity. Humic acid contains adequate concentration of NPK, and decrease in pH of the soil is also conducive to plant growth. Dufault [32] observedthat humic acid increased fruit set. Similarly, Albregts and Howard [33] showed that soil applied potassium fertilizer increased fruit number of strawberries. Fisher [34] concluded that high levels of potassium increased the number of fruits produced in tomato. In the same line [35] reported that, potassium application increased fruit number of tomato. Adebooye and Oloyede [36] alsofound that the number of marketable fruits and overall fruit yield increased to a certain level with potassium fertilizer application.

Yield (Tons ha^{-1}): Data pertaining to the yield (tons ha^{-1}) of squash was significantly (P<0.001) influenced by humic acid and potassium application rates. However, the interaction between humic acid and potassium was also found significant (P<0.05), as shown in Figure 6. Interaction between humic acid and potassium levels (Figure 6) indicates that the application of 20 kg HA ha^{-1} with different doses of K increased the yield to a maximum of 21.3 tons ha^{-1} at 90 kg K ha^{-1} dose, but then declined above this dose, such that plants receiving 120 kg K ha^{-1} attained the yield of 19.8 tons ha^{-1}. The differences between the HA treatments were minimal upto 60 kg K ha^{-1}, but above this K level, the yield rocketed at 90 kg K ha^{-1} only with 20 kg ha^{-1} HA application. However, 10 kg HA ha^{-1} showed similar as that of no HA application at 90 and 120 kg K ha^{-1}. This seems astonishing, the reason for which is not clear and needs further investigation. In the current study humic acid and potassium increasedthe yield of squash, this increase might be due to consistent increase in fruit number, fruit weightand fruit diameter. The yield components may also be increased due to high starch synthesis and translocation activities stimulated by HA and K application. Eltilib *et al*. [18] stated that humic acid increased yield and yield components. HA applications can result in an increase and improvement in the fruit yield and quality [37]. Xiumeil and Yaping [38] showed that the use of potassium

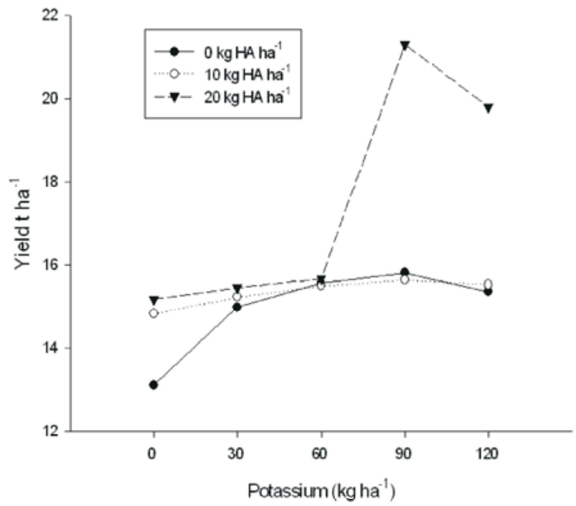

Fig. 6: Interactive effect of humic acid and potassium on yield t ha^{-1}

has a major role in increasing the yield. Hartz, [39] revealed that potassium was linked with tomato fruit yield and quality. In the present study, K increased yield components of squash compared to the control. Similarly, Ahmed *et al*. [40] concluded that, soil potassium significantly increased the yield of most vegetable crops such as tomato, onion, okra, potatoes and eggplant. Adequate supply of K is important for starch synthesis and translocation and it also increases yield [41].

CONCLUSIONS AND RECOMMENDATION

On the bases of results obtained, the following conclusions are drawn. Humic acid at higher level (20 kg ha^{-1}) improved growth and yield of squash. Application of potassium at the rate of 90 kg ha^{-1} performed better in term of growth and yield of squash. Interactive effect of humic acid (20 kg ha^{-1}) and potassium (90 kg ha^{-1}) increased growth and yield of squash.On the bases of conclusion obtained it is recommended that both humic acid (20 kg ha^{-1}) and potassium (90 kg ha^{-1}) for better growth and yield of squash.

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