J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 12 (7):469-479, 2021

Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Response of Soybean (*Glycine max* L.) Plant and Soil Properties to NPK Fertilization and Humate Substances Application under Different Tillage Systems

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ABSTRACT

To evaluate effects of NPK and potassium humate application under two tillage systems, i.e., no tillage (direct sowing) and full tillage, on soybean productivity, field experiment was conducted in successive seasons of 2019 and 2020. The experimental design used was a split-split, with four replications. Results indicated that tillage system had no effect on soybean productivity, except nodulation parameters, where no-tillage system gave the highest number of nodules plant^{-1} and dry weight of nodules plant than full tillage. Fertilization with NPK enhanced all studied growth parameters, i.e., plant height, nodulation, yield components (number of pods plant^{-1}, number of seeds pod^{-1} and 100-seed weight), yield measurements (seed and straw yields), N, P and K concentrations in seeds and straw as well as seed quality (protein and oil percentages and yields) when compared with control. Phosphorus had more pronounced effect than the other two nutrients. Also, application of 24 kg potassium humate as soil application improved all the above-mentioned quality and quantity of soybean plants. Moreover, no tillage and potassium humate application improved soil reaction, organic matter, bulk density, soil available water and wilting point after soybean harvesting. From these results, it could be concluded that cultivating soybean plants without no tillage, fertilizing with 72, 33 and 95 kg N, P and K ha^{-1} and 24 kg potassium humate ha^{-1} as soil application is recommended in order to maximize soybean productivity, meanwhile minimize its costs.

Keywords: Soybean, Tillage, NPK Fertilizers, Potassium Humate.

INTRODUCTION

Soybean plants (*Glycine max* L) is one of the most important legumes all over the world. It has been cultivated under semi-arid conditions, and its important due to its high-quality protein (about 40%) and oil (21%) and its ability to fix about 95-720 kg ha^{-1} nitrogen, it contains certain essential amino acids, vitamins B_1, B_2 B_6 as well as flavors in its seeds (El-Ghamry *et al*., 2018). The area cultivated with soybean is declined in Egypt, where it reached to about 137859 hectares in 2016, while Egypt consumes about 3.93 million MT in 2019/2020 represent about 14% from local production (El-Sayed *et al*., 2020).

There are many managements are more important for increasing soybean production beside tillage such as planting date, row spacing, cultivar selection and fertilization. The importance of tillage depending on some field conditions, e. g., drainage and soil borne pathogens. Recently, no tillage method is preferred due to use of some machines for planting and herbicides and weed control (Iowa State University of Science and Technology, 2020). They added, tillage is more expensive, increases soil erosion, consumed more time, meanwhile in many cases is not increase soybean yield. However; nutrients, especially the non-mobile as phosphorus can become stratified in no-tillage systems, where higher concentration of phosphorus exists in top soil and are less accessible to roots. Therefore, soil tests should be performed to state the nutrient level at root depth to know the need for fertilizer application. Additionally, reduced tillage preserves soil moisture in case of drought, improve water quality, increase organic matter in soil, reduce the losses of nutrients by leaching, decrease the irrigation cost and reduce soil erosion. Mathew, *et al.* (2012) added that reducing tillage improved soil carbon and nitrogen content, increased microbial population and the activities of phosphatase in soil. The benefits of no-tillage system have been elaborated by many workers such as Kihara, *et al*. (2012), Omondi, *et al.* (2014), Hosseini, *et al.* (2016), Kandel, *et al*. (2019) and Yu, *et al*. (2020).

The macronutrients, N, P and K are essential in plant growth, it present in high level of soybean, and play important functions in plant growth, therefore it significantly affects various soybean traits (Darwesh, *et al*., 2013; Beinsen, *et al*., 2020; and El-Sayed, 2020). Under low nitrogen content in soil, the addition of small amount of nitrogen enhances rhizobia formation, improves the growth of legume plant seedling (Yin *et al*., 2018). Soybean plant cannot efficiency fix atmospheric nitrogen during the early growth stages before the branches develop due to it has few or no rhizobia. Application of nitrogen fertilizer during the early growth stage enhances vegetative growth which in

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DOI: 10.21608/jssae.2021.83672.1018

turn led to maximum yield (Yanni *et al*., 2001). The rhizobia increase as the plant growth increases, and its ability of nitrogen fixation increased. On the other hand, rhizobia activity is inhibited during the late growth period accordingly, flower pod differentiation and yield formation are negatively affected (Bethlenfalvay *et al*., 1982), therefore excess nitrogen fertilizer is needed. Phosphorus application improves root growth, drought tolerance, disease resistance, and improve nutrient and water absorption in the plant after they have depleted their endosperm reserves (Jian *et al*., 2014). Potassium fertilizers enhance the metabolism of sugar, improves osmotic cell concentration, participates in photosynthesis, maintains stomata guard cell turgor, regulate stomatal opening, improve drought resistance, and increases the plant productivity (liang *et al*., 2011). The crop production is depended to the appropriate use of fertilizers. Low fertilization levels declined yield and its quality as well as imbalanced N, P and K fertilization (Asaduzzaman *et al*., 2008; Abd El-Azeim *et al*., 2020; Abd El-Azeim *et al*., 2021). Meanwhile, excessive application of fertilizers has adverse effect on product quality, soil microorganism's activity, and encouraged soil-borne diseases (Jian *et al*., 2007; Abo Shelbaya *et al*., 2021), therefore soybean productivity can be improved by using balanced fertilizers (El-Sayed *et al*., 2020)

The use of bulky organic fertilizers has been spread by the farmers, which it needs to much number of laborers for transportation and supplied to soil. Therefore, it is necessary to go for the end product of organic manure decomposition such as humic substances. The humic substances include humus, humin, humic acid, humate, and fulvic acid having many beneficial effects on plants and soil, e. g., it helps to improve soil compactness, supply the plants with macro- and micronutrients, improve soil water relations, enhanced microbial population and activity, and increased the germination rates. Also, it improved some soil properties, such as soil aggregation, permeability, aeration, water holding capacity, help the plant to absorb nutrients from insoluble form, (Tan, 2003), and it plays as growth regulators. Additionally, Chen *et al*. (2001) and Nardi *et al*. (2002) mentioned that humic acids stimulate vegetative growth, hence increased yield and quality by acting on many mechanisms include, membrane permeability, cell respiration, photosynthesis, protein formation, nutrient and water uptake and enzyme activities. Many authors reported the positive effect of humic acid application on soybean plant such as Slamani *et al*. (2017), Savita *et al*. (2018) and Bahrun *et al*. (2019). Therefore, this study was performed to investigate the effect of tillage system and potassium humate under N, P and K fertilization on quality and quantity of soybean plant as well as some soil properties after soybean harvest.

MATERIALS AND METHODS

The setup of the experiment

Field experiment was conducted during two successive seasons of 2019 and 2020 at the Farm of Sids Agricultural Research Station (Lat. 29º 04 ¯ N, long. 31º 06¯E and 30.4 m above sea level), ARC, Beni-Suef Governorate, Egypt to study the possibility of reducing tillage system under N, P and K fertilization as well as soil application of humate potassium, and its effect on quality and quantity of soybean plant. The soil of both seasons was clay in texture had pH of 7.9 and 8.0, EC of 1.19 and 1.25 (dS m^{-1}), organic matter of 1.82 and 1.89 %, bulk density of 1.23 and 1.20 (g cm^{-3}), soil available water of 21.69 and 21.56% and wilting point of 20.32 and 20.08% as well as soil available N of 24 and 21 µgg^{-1}, P of 12 and 10 µgg^{-1} and K of 187 and 179 µgg^{-1}, respectively (according to A. O. A. C, 1990).

The experimental design and treatments

The experiment was laid out in a split-split design with three factors in complete randomized blocks with four replications. The factors were: (A) tillage system (no tillage and full tillage), (B) NPK fertilization (control, NP, NK, PK and NPK), and (C) soil application of humate potassium (without and 24 kg ha^{-1} humate potassium as soil application). The tillage system was located in the main plots and NPK fertilization was arranged in sub plots, while humate potassium treatments were applied in sub-sub plots. The tillage (T) treatments were no tillage (T_1) as direct sowing and full tillage (T_2) as two passes of disk. Nitrogen and potassium fertilization were added as ammonium nitrate (33.5% N) and potassium sulphate (48% K_2O) fertilizers at rates of 72 and 95 kg N and K ha^{-1}, respectively in two equal doses, the first before the first irrigation and the other before the second irrigation. Whereas, phosphorus treatments were added before sowing during plant preparation at rate of 33 kg P ha $^{-1}$. However, humate potassium treatments were added before planting during land preparation. Other culture practices for soybean production in district were done as usual.

The plantation of soybean

Soybean seeds variety Giza 111 was inoculated with specific *Rhizopum Japoncum* strain and then directly sown in 5 and 10 June in both growing seasons, respectively in rows or ridges for no tillage (T_1) and full tillage (T_2), respectively in hills 5 cm a part and 60 cm rows or ridges, the plot size were 10.5 m^2 (3×3.5 m). The plants were thinned after 21 days from sowing to one plant.

Data recorded

- After 48 days from sowing, ten plants were taken randomly from two middle rows or ridges of every plot for nodules account. Plant samples were dug out with a boll of soil and the soil was carefully removed: the roots were washed, and the nodules were removed, counted and oven-dried at 70 ºC for two days and weighed.
- Ten plants at 75 days from sowing were taken randomly from the middle of rows or ridges of every plot to measure plant height (cm).
- Also, ten plants were randomly taken from the middle of rows or ridges of every plot at harvest to measure yield components, i.e.; number of pods $plant^{-1}$, number of seeds $pods^{-1}$ and 100-seed weight (g).

-Seed and straw yields were determined for each plot and converted to kg ha^{-1}.

-Samples of seeds and straw were taken to determine N, P and K concentration.

-Protein percentage in seeds were calculated by multiplying nitrogen percentage by 6.25 and then converted to protein yield by multiplying protein (%) by seed yield.

-Oil percentage in seeds were determined (according to A. O. A. C, 1990) and converted to oil yield by multiplying oil (%) by seed yield.

Statistical analysis

The obtained results were subjected to the analysis of variance according to Snedecor and Cochran (1980). The differences between treatments were compared by using L. S. D. test at 0.05 level of probability in both seasons.

RESULTS AND DISCUSSION

Dry weight and nodulation

The data in Table 1 show that tillage system was significantly affected number of nodules/plant and the dry weight of nodules/plant, while the dry weight of plant unaffected. The no tillage system (T_1) resulted in significant increases in both nodulation parameters than full tillage (T_2). The increment in those parameters due to T_1 reached to 6.2 and 8.1% over T_2 system, respectively in the first season. The corresponding increases in the second season were 4.0 and 16.2%. The enhancement of nodulation due to no tillage may be attributed to minimal disturbance of the soil surface resulted in more microbial activity (Omondi *et al*., 2014). These results are in line with those obtained by Van Kessel and Hartley (2000) and Omondi *et al*. (2014) who stated that nitrogen fixed biologically by legume plants were increased under no tillage due to improving its nodulation. However, Omondi *et al.* (2014) and Kandel *et al.* (2019) reported that shoot dry weight of soybean unaffected by tillage method.

Table 1. Response of dry weight and nodulation of soybean plants to tillage system, NPK fertilization and potassium humate application.

Treatments			First season			Second season		
Tillage (A)	NPK (B)	Potassium humate (C)	Dry weight plant^{-1} (g)	No of nodules plant^{-1}	Dry weight of nodules plant^{-1}	Dry weight plant^{-1} (g)	No of nodules plant^{-1}	Dry weight of nodules plant^{-1}
No Tillage (T_1)	0.0	Without	14.8	24.5	1.12	12.2	20.6	1.01
	NP		16.1	33.3	1.57	14.6	30.6	1.43
	NK		15.9	30.0	1.39	14.5	27.1	1.32
	PK		17.7	37.1	1.72	15.2	33.8	1.67
	NPK		19.2	33.9	1.55	17.7	30.1	1.50
	mean		16.7	31.8	1.47	14.8	28.4	1.39
	0.0	With	17.5	29.1	1.34	14.6	26.5	1.27
	NP		19.6	38.5	1.78	15.2	35.8	1.66
	NK		18.8	34.8	1.62	15.3	31.3	1.56
	PK		20.4	43.1	2.02	17.6	40.3	1.85
	NPK		22.1	39.3	1.83	19.6	36.6	1.78
	mean		19.7	37.0	1.72	16.5	34.1	1.62
Mean			18.2	34.4	1.60	15.7	31.3	1.51
Full tillage (T_2)	0.0	Without	14.9	22.4	1.00	12.5	20.5	0.85
	NP		16.3	31.5	1.41	14.1	28.6	1.34
	NK		15.0	28.8	1.33	14.7	26.3	1.17
	PK		17.8	35.2	1.63	15.4	33.1	1.49
	NPK		19.4	31.6	1.43	17.3	29.7	1.25
	mean		16.7	29.9	1.36	14.8	27.6	1.22
	0.0	With	17.7	27.6	1.28	14.8	25.1	1.03
	NP		19.5	36.1	1.68	15.7	33.9	1.44
	NK		18.1	32.3	1.45	15.6	30.0	1.25
	PK		20.6	41.5	1.86	17.2	38.9	1.69
	NPK		22.0	37.1	1.69	19.3	35.2	1.43
	mean		19.6	34.9	1.59	16.5	32.6	1.37
Mean			18.2	32.4	1.48	15.7	30.1	1.30
Mean of NPK		0.0	16.2	25.9	1.19	13.5	23.2	1.04
		NP	17.9	34.9	1.61	14.7	32.2	1.47
		NK	17.0	31.2	1.45	15.0	28.7	1.33
		PK	19.1	39.2	1.81	16.4	36.5	1.68
		NPK	20.7	35.5	1.63	18.5	32.9	1.49
Mean of potassium humate		Without	16.7	30.9	1.42	14.8	28.0	1.31
		With	19.7	36.0	1.66	16.5	33.4	1.50
L.S.D at 0.05								
A			NS	1.11	0.13	NS	1.06	0.10
B			1.03	2.35	0.19	1.01	2.17	0.15
C			1.25	3.07	0.12	1.20	2.85	0.10
AB			NS	NS	NS	NS	NS	NS
AC			NS	NS	NS	NS	NS	NS
BC			NS	NS	NS	NS	NS	NS
ABC			NS	NS	NS	NS	NS	NS

As for the effect of NPK fertilization, the data revealed that the dry weight/plant, number of nodules/plant and dry weight of nodules/plant were significantly responded to NPK application. It could be arranged the effect of NPK treatments on these parameters as the following descending order: NPK > PK > NP > PK > control.

It is obvious to notice that phosphorus fertilizer is the more pronounced effect on these parameters when combined with nitrogen and/or potassium fertilizer. In this concern, Plaxton (2004) and Schulze *et al.* (2006) mentioned that the symbiotic nitrogen fixation consumes great amount of energy which depends to the presence of available phosphorus. These results are in line with those obtained by Abbasi *et al*. (2010) and Dhadave *et al.* (2018) for soybean dry weight, and Servani *et al*. (2014) for soybean nodulation.

With respect to the effect of potassium humate, data clearly show that potassium humate application had a positive effect on dry weight/plant, number of nodulation/plant and dry weight/plant. Comparing with control, added potassium humate increased these parameters by about 13.8, 16.5 and 16.9% in the first season. The corresponding increases in the second season were 11.5, 19.3 and 14.5%. The improvement of soybean nodulation may be due to humate substances resulted to greater nutrient uptake into plant roots (Kulikva *et al*., 2005). Also, Zandonadi *et al*., 2007) reported that humic acid can improve lateral root growth by activating cell membrane. Moreover, the primitive effect of humic acid on growth parameters may be due to humic acid can act on some processes such as respiration, photosynthesis, water and nutrient adsorption, protein synthesis, enzyme activation and enhance microbial population (Abbasi, 2013). These results are similar to those obtained by Gad El-Hak *et al*. (2012) for peas plant and Ismail *et al*. (2016) for faba bean plants.

Data of the interaction revealed that plant dry weight and nodulation was not affected by the interaction between treatments which is presumably attributed to many factors that the studied factors are acting independently and is not related to one another. In general, the plants received NPK + potassium humate under no tillage or full tillage recorded the heaviest soybean dry weight, while the plants supplied with NPK + potassium humate under no tillage gave the greatest number of nodules/plant and dry weight of nodules/plant.

Yield components

The data in Table 2 show that the yield components of soybean, namely, number of pods/plants, number of seeds/pod and 100-seed weight was not affected by tillage system. Whereas these parameters were significantly responded to NPK and humate potassium applications. Comparing with control, the treatments of NP, NK, PK and NPK gave higher values of yield components. It could be arranged the effect of the studied macronutrients on these parameters on the descending order as follow: NPK > NP > PK > NK > Controls. It is worthy to notice that phosphorus is the more pronounced nutrient affecting soybean yield components, which mainly due to its positive effect on the growth and nodulation as mentioned before (Table 1).

Table 2. Response of yield components of soybean plants to tillage system, NPK fertilization and potassium humate application.

Tillage (A)	NPK (B)	Potassium humate (C)	First season: No of pods/ plant	First season: No of seeds/ pod	First season: 100 - seed weight (g)	Second season: No of pods/ plant	Second season: No of seeds/ pod	Second season: 100 - seed weight (g)
No Tillage (T_1)	0.0	Without	17.6	2.05	10.06	16.5	2.01	10.01
	NP		19.4	2.13	11.25	18.2	2.10	11.20
	NK		18.2	2.09	11.02	16.9	2.05	11.10
	PK		21.1	2.18	12.86	20.0	2.14	12.78
	NPK		24.0	2.23	12.95	23.4	2.19	12.79
	mean		20.1	2.14	11.63	19.0	2.10	11.58
	0.0	With	21.9	2.10	11.21	20.7	2.05	10.02
	NP		23.7	2.24	12.31	22.9	2.20	11.21
	NK		22.1	2.18	12.06	22.0	2.15	11.01
	PK		24.7	2.27	13.21	23.6	2.23	12.75
	NPK		26.9	2.23	13.60	24.8	2.29	12.79
	mean		23.9	2.22	12.48	22.8	2.18	11.56
Mean			22.0	2.18	12.06	20.9	2.14	11.57
Full tillage (T_2)	0.0	Without	17.5	2.04	9.65	16.4	2.02	10.02
	NP		19.3	2.12	11.07	18.6	2.08	11.22
	NK		18.7	2.10	10.95	16.5	2.06	11.12
	PK		21.6	2.19	12.22	20.3	2.13	12.75
	NPK		23.5	2.23	12.61	23.2	2.19	12.74
	mean		20.2	2.14	11.30	19.0	2.10	11.57
	0.0	With	21.6	2.12	11.03	20.8	2.06	10.01
	NP		23.9	2.22	12.15	22.5	2.21	11.23
	NK		21.2	2.17	11.96	22.1	2.14	11.14
	PK		24.8	2.28	12.85	23.4	2.22	12.76
	NPK		26.5	2.33	13.03	24.6	2.28	12.78
	mean		23.6	2.22	12.20	22.7	2.18	11.58
Mean			21.9	2.18	11.75	20.9	2.14	11.58
Mean of NPK		0.0	19.7	2.08	10.49	18.6	2.04	10.02
		NP	21.6	2.18	11.70	20.6	2.15	11.22
		NK	20.1	2.14	11.50	19.7	2.10	11.09
		PK	23.1	2.23	12.79	21.8	2.18	12.76
		NPK	25.2	2.29	13.05	24.0	2.24	12.78
Mean of potassium humate		Without	20.2	2.14	11.47	19.0	2.10	11.58
		With	23.8	2.22	12.34	22.8	2.18	11.57
L.S.D at 0.05								
A			NS	NS	NS	NS	NS	NS
B			0.87	0,02	0.38	0.75	0.02	0.33
C			0.90	0.03	0.45	0.71	0.02	NS
AB			NS	NS	NS	NS	NS	NS
AC			NS	NS	NS	NS	NS	NS
BC			NS	NS	NS	NS	NS	NS
ABC			NS	NS	NS	NS	NS	NS

With respect to the effect of potassium humate, the data indicate that potassium humate application had a positive effect on the studied yield components, except 100-seed weight in the second season. The increment of number of pods/plant, number of seeds/pod and 100-seed weight were 17.8, 2.2 and 7.6% in the first season, respectively.

Same trends were obtained in the second season for number of pods/plant and number of seeds/pod. The enhancement of yield components due to potassium humate application is mainly attributed to positive effect of humate on plant dry weight and nodulation as abovementioned discussed. These results are similar to those obtained by El-Shafey and Zen El-Dein (2016) for soybean plant and Dawood *et al.* (2019) for faba bean plants.

The data in Table 2 indicate that soybean yield components was not affected by the interaction between treatments. In general, the treatment of NPK + potassium humate under any tillage method exhibited the highest values of yield components, while the treatment of without any of NPK or potassium humate under no or traditional system recorded the lowest ones.

Seed and straw yields

Data in Figs 1 and 2 represent the effect of tillage methods, NPK fertilization and humate potassium application on seed and straw yields of soybean plants. As for the effect of tillage, data show that both seed and straw yield were not affected by tillage system. This means that reducing tillage did not led to decreasing soybean yield. Many workers stated that no tillage gave yields in part to that under full tillage such as Omondi *et al.* (2014) and Kandel *et al.* (2019) for soybean, and Pipars and Mansour (2019) for peanut, and Nkongolo and Haruna (2015) for maize.

Concerning NPK fertilization, data clearly indicated that soybean yields were significantly affected by NPK application. It could arrange the effect of NPK fertilizers on seed and straw yields on the following descending order: NPK > PK > NP >NK > Control. The data clearly show that the treatments included phosphorus surpassed other treatments. The primitive effect of phosphorus on soybean production may be attributed to its positive effect on N_2-fixation, nitrogen activity, root growth, photosynthesis, flowering and seed formation (Ogoke *et al*., 2003). These results are in line with those obtained by Suman *et al.* (2018) and Yacoub *et al.* (2020).

Data show that soybean yields were positively affected by potassium humate application. Comparing with no potassium humate, added potassium humate led to about 17.8 and 14.8 % increasing of seed and straw yields in the first season, respectively. The corresponding increases in the second season were 17.0 and 17.0 % in the same respect. In this concern, Aydin *et al.* (2012) mentioned that humic acid regulates hormone level, enhance vegetative growth, increase the plant resistance to stress tolerance, stimulate root growth and increased nutrient adsorption. These results are similar to those obtained by El-Shafey and Zen El-Dein (2016) and Dawood *et al.* (2019).

Data of the interaction indicated that soybean yields was not affected by the interaction between treatments in both seasons. In general, the soybean plants supplied with NPK fertilizer plus potassium humate under no tillage or full tillage recorded the higher soybean yields. Whereas, the plants without NPK and potassium humate application under any of the two-tillage system exhibited the lowest seed or straw yields.

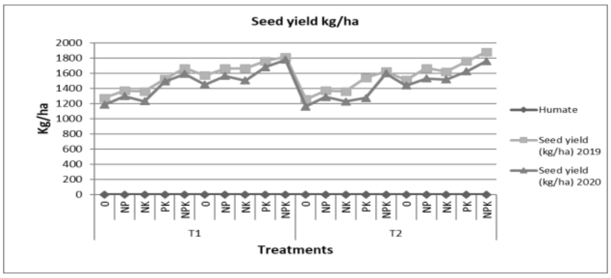

Figure 1. Response of seed yield of soybean plants to tillage system, NPK fertilization and potassium humate application.

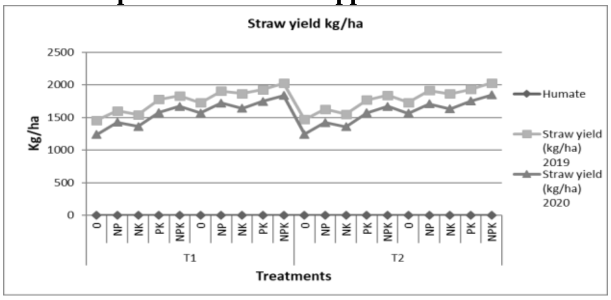

Figure 2. Response of straw yield of soybean plants to tillage system, NPK fertilization and potassium humate application.

N, P and K concentration

The data in Tables 3 and 4 represent the effect of tillage methods, NPK and humate potassium application on N, P and K concentration in soybean seeds and straw. Data show that NPK concentration in seeds and straw was not affected by tillage methods in both studied seasons. Similar results were obtained by Vyn *et al.* (2002) who reported that tillage treatments did not affect ear-leaf nitrogen and potassium concentration in maize plants.

As for NPK treatments, the data reveal that N, P and K percentages in both seeds and straw were significantly responded to NPK fertilization. The NP, NK, PK and NPK treatment gave higher N, P and K concentration in seeds or straw than control. Statistically it could arrange the effect of NPK fertilization on N, P and K concentration in soybean seeds and straw in the descending order as follow: NPK=PK > NP > NK > control. It is worthy to notice that the effect of phosphorus on nutrient concentration is more pronounced than the other two nutrients which mainly due to phosphorus application improve the root growth, in turn enhanced nutrient adsorption (Darwish *et al*, 2013). These results are in line with those obtained by Afra and Mozafar (2017) and Yacoub (2021) who stated that phosphorus application improved nutrient uptake by soybean plants.

Regarding the effect of potassium humate, the data indicate that N, P and K concentration in soybean seeds and straw were significantly increased as a result to potassium humate application. The increment in N, P and K caused by added humate potassium in seeds reached to 5.2, 19.1 and 14.2% over without humic acid in the first season. Similar trends were obtained in the second season and for straw. The beneficial effect of humic acid on nutrient uptake is mainly due to potassium humate are naturally oxidized, in turn gives them a negative charge which attracted with the cation nutrients, such as NH_4 and K^+, and prevent this nutrient to unlock from soil. Then these nutrients transfer to plant root. However, its effect on phosphorus is mainly due to humic acid decreased soil pH, consequently increased its availability (Rajpar *et al*., 2011). These results agree with those obtained by Slamani *et al.* (2017) and Savita *et al.* (2018) who reported that humic acid improved N, P and K adsorption by soybean plant.

Table 3. Response of N, P and K concentrations in soybean seeds to tillage system, NPK fertilization and potassium humate application.

Treatments			First season			Second season		
Tillage (A)	NPK (B)	Potassium humate (C)	N%	P%	K%	N%	P%	K%
No Tillage (T_1)	0.0	Without	5.03	0.25	1.28	5.00	0.28	1.22
	NP		5.61	0.55	1.29	5.42	0.59	1.26
	NK		5.37	0.37	1.95	5.26	0.41	1.93
	PK		5.84	0.56	1.97	5.71	0.59	1.95
	NPK		6.07	0.56	1.96	6.01	0.58	1.95
	mean		5.58	0.46	1.69	5.48	0.49	1.66
	0.0	With	5.37	0.39	1.60	5.32	0.42	1.57
	NP		5.89	0.64	1.61	5.81	0.65	1.58
	NK		5.66	0.47	2.13	5.73	0.51	2.11
	PK		6.13	0.65	2.14	6.12	0.68	2.11
	NPK		6.32	0.64	2.13	6.24	0.68	2.13
	mean		5.87	0.56	1.92	5.84	0.59	1.90
Mean			5.73	0.51	1.81	5.66	0.54	1.78
Full tillage (T_2)	0.0	Without	5.02	0.24	1.25	4.95	0.29	1.20
	NP		5.64	0.57	1.28	5.50	0.59	1.25
	NK		5.41	0.39	1.97	5.36	0.43	1.94
	PK		5.89	0.56	1.96	5.67	0.58	1.94
	NPK		6.05	0.56	1.96	6.00	0.59	1.96
	mean		5.60	0.47	1.68	5.50	0.50	1.66
	0.0	With	5.34	0.37	1.58	5.30	0.41	1.58
	NP		5.92	0.65	1.64	5.78	0.63	1.60
	NK		5.63	0.50	2.16	5.74	0.50	2.13
	PK		6.15	0.64	2.14	6.10	0.69	2.11
	NPK		6.38	0.65	2.15	6.22	0.67	2.12
	mean		5.88	0.56	1.93	5.83	0.58	1.91
Mean			5.74	0.52	1.81	5.67	0.54	1.79
Mean of NPK		0.0	5.19	0.31	1.43	5.39	0.35	1.39
		NP	5.77	0.60	1.46	5.63	0.62	1.42
		NK	5.22	0.43	2.05	5.52	0.46	2.03
		PK	6.00	0.60	2.05	5.90	0.64	2.03
		NPK	6.21	0.60	2.05	6.11	0.63	2.04
Mean of potassium humate		Without	5.59	0.47	1.69	5.49	0.50	1.66
		With	5.88	0.56	1.93	5.84	0.59	1.91
L.S.D at 0.05								
A			NS	NS	NS	NS	NS	NS
B			0.23	0.10	0.13	0.24	0.12	0.14
C			0.20	0.20	0.14	0.17	0.06	0.13
AB			NS	NS	NS	NS	NS	NS
AC			NS	NS	NS	NS	NS	NS
BC			NS	NS	NS	NS	NS	NS
ABC			NS	NS	NS	NS	NS	NS

Table 4. Response of N, P and K concentrations in soybean straw to tillage system, NPK fertilization and potassium humate application.

Treatments			First season			Second season		
Tillage (A)	NPK (B)	Potassium humate (C)	N%	P%	K%	N%	P%	K%
No Tillage (T_1)	0.0	Without	3.75	0.12	0.79	3.60	0.14	0.73
	NP		4.13	0.36	0.79	4.00	0.37	0.72
	NK		3.96	0.25	0.92	3.83	0.29	0.85
	PK		4.40	0.35	0.93	4.26	0.36	0.86
	NPK		4.57	0.39	0.93	4.33	0.42	0.86
	mean		4.16	0.29	0.87	4.00	0.32	0.80
	0.0	With	3.91	0.17	0.85	3.75	0.20	0.83
	NP		4.40	0.40	0.84	4.17	0.43	0.84
	NK		4.25	0.29	0.98	3.97	0.32	0.96
	PK		4.59	0.40	0.98	4.42	0.42	0.97
	NPK		4.68	0.44	0.99	4.58	0.47	0.97
	mean		4.37	0.34	0.93	4.18	0.37	0.91
Mean			4.27	0.32	0.90	4.09	0.35	0.86
Full tillage (T_2)	0.0	Without	3.73	0.13	0.78	3.58	0.15	0.74
	NP		4.15	0.35	0.79	4.02	0.36	0.73
	NK		3.96	0.25	0.93	3.81	0.30	0.86
	PK		4.43	0.36	0.92	4.25	0.36	0.85
	NPK		4.62	0.40	0.93	4.34	0.43	0.86
	mean		4.18	0.30	0.87	4.00	0.32	0.81
	0.0	With	3.90	0.18	0.86	3.76	0.19	0.83
	NP		4.43	0.42	0.85	4.16	0.44	0.85
	NK		4.27	0.31	0.99	3.99	0.31	0.97
	PK		4.60	0.40	0.98	4.43	0.42	0.96
	NPK		4.65	0.45	0.98	4.57	0.48	0.97
	mean		4.37	0.35	0.93	4.18	0.37	0.92
Mean			4.28	0.33	0.90	4.09	0.35	0.87
Mean of NPK		0.0	3.82	0.15	0.82	3.67	0.17	0.76
		NP	4.28	0.38	0.82	4.09	0.40	0.79
		NK	4.11	0.28	0.96	3.90	0.31	0.91
		PK	4.51	0.38	0.95	4.38	0.39	0.91
		NPK	4.63	0.42	0.96	4.46	0.45	0.92
Mean of potassium humate		Without	4.17	0.30	0.87	4.00	0.32	0.81
		With	4.37	0.35	0.93	4.09	0.37	0.92
L.S.D at 0.05								
A			NS	NS	NS	NS	NS	NS
B			0.15	0.06	0.05	0.13	0.07	0.04
C			0.09	0.02	0.03	0.06	0.02	0.05
AB			NS	NS	NS	NS	NS	NS
AC			NS	NS	NS	NS	NS	NS
BC			NS	NS	NS	NS	NS	NS
ABC			NS	NS	NS	NS	NS	NS

The data of the interaction indicate that N, P and K concentration in seeds and straw of soybean was not affected by the interaction between treatments. The treatment of NPK or PK + potassium humate under any tillage methods gave the highest N, P and K concentrations. On the other hand, the treatment of without both of NPK and potassium humate under no or full tillage recorded the lowest ones.

Seed quality

The data in Table 5 represent the effect of tillage, NPK fertilization and potassium humate application on seed quality of soybean in term of protein and oil percentages and yields. The obtained results show that tillage system did not affect seed quality in both seasons.

Table 5. Response of protein and oil percentages and yields in soybean seeds to tillage system, NPK fertilization and potassium humate application.

Treatments			First season				Second season			
Tillage (A)	NPK (B)	Potassium humate (C)	Protein (%)	Protein yield(kg ha^{-1})	Oil (%)	Oil yield (Lha^{-1})	Protein (%)	Protein yield(kg ha^{-1})	Oil (%)	Oil yield (Lha^{-1})
No Tillage (T_1)	0.0	Without	31.44	400.70	18.32	233.49	31.25	370.38	18.01	229.54
	NP		35.06	480.04	21.29	291.50	33.88	439.22	21.03	287.94
	NK		33.56	456.62	20.15	274.16	32.88	404.62	20.00	272.12
	PK		36.50	599.29	21.41	328.07	35.69	531.67	21.25	325.61
	NPK		37.94	628.55	21.65	360.62	37.56	597.99	21.41	356.63
	mean		34.90	513.24	20.56	297.57	34.25	432.78	20.34	298.54
	0.0	With	33.56	526.96	18.86	296.14	33.25	482.22	18.61	292.22
	NP		36.81	611.97	21.75	361.59	36.31	567.42	21.56	358.44
	NK		35.38	588.26	20.69	344.01	35.81	538.80	20.46	340.19
	PK		38.31	674.75	21.86	385.02	38.25	643.10	21.71	382.38
	NPK		39.50	716.25	22.17	402.01	39.00	692.56	22.06	400.01
	mean		36.71	623.64	21.07	357.75	36.52	584.82	20.87	354.65
Mean			35.81	568.44	20.82	327.66	35.39	508.80	20.61	326.60
Full tillage (T_2)	0.0	Without	31.38	394.16	18.61	233.76	30.94	359.62	18.03	226.47
	NP		35.25	483.00	21.40	293.22	34.38	442.61	21.05	288.43
	NK		33.81	459.85	20.26	275.56	33.50	410.98	20.02	272.29
	PK		36.81	566.62	21.47	330.49	35.44	521.85	21.27	327.41
	NPK		37.81	614.30	21.71	352.72	37.50	598.65	21.42	348.01
	mean		35.01	503.59	20.69	297.15	34.35	466.74	20.16	292.52
	0.0	With	33.38	5.4.57	18.90	285.69	33.13	475.81	18.63	281.61
	NP		37.00	616.90	21.79	363.30	36.13	553.40	21.53	359.97
	NK		35.19	570.61	20.73	336.14	35.88	544.26	20.44	311.14
	PK		38.44	676.12	21.90	385.20	38.13	619.42	21.72	382.03
	NPK		39.88	749.66	22.19	417.13	38.88	685.03	22.05	414.50
	mean		36.78	623.57	21.10	357.49	36.43	575.58	20.87	349.85
Mean			35.90	563.58	20.90	327.32	35.39	521.16	20.52	321.19
Mean of NPK		0.0	32.57	456.60	18.67	262.27	32.14	422.01	18.32	257.46
		NP	36.03	547.98	21.56	327.40	35.18	500.66	21.29	323.70
		NK	34.84	518.84	20.77	307.47	34.52	474.67	20.23	298.94
		PK	36.27	629.20	21.66	357.20	36.88	579.01	21.49	354.36
		NPK	38.78	677.19	21.93	383.12	38.24	643.56	21.74	379.79
Mean of potassium humate		Without	34.96	508.42	20.63	297.36	34.30	499.76	20.25	295.53
		With	36.75	556.00	20.96	357.62	36.48	580.20	20.87	338.23
L.S.D at 0.05										
A			NS	NS	NS	NS	NS	NS	NS	NS
B			o.83	10.37	0.25	7.65	0.77	9.82	0.25	6.13
C			0.79	9.15	0.18	8.11	0.76	8.94	0.29	6.99
AB			NS	NS	NS	NS	NS	NS	NS	NS
AC			NS	NS	NS	NS	NS	NS	NS	NS
BC			NS	NS	NS	NS	NS	NS	NS	NS
ABC			NS	NS	NS	NS	NS	NS	NS	NS

As for the effect NPK fertilization, the data indicate that protein (%) and yield as well as oil (%) and yield were significantly responded to NPK application. Seed quality was improved under N, P and K addition in comparison to control. It could arrange these effective in the descending order as follow: NPK > PK > NP > NK > control. It is obvious to notice that the effect of phosphorus is more pronounced on seed quality than nitrogen and potassium. The positive effect of phosphorus is mainly due to phosphorus is an essential compound for DNA and RNA which needed for protein synthesis (Luikhan *et al*., 2018). In addition, Dwivedi and Bapat (1998) reported that fatty acids formation and their esterification were needed for phosphorus. These results are in harmony with those obtained by Suman *et al*. (2018) and Yacoub *et al*. (2020) who reported that protein and oil percentages and yields of soybean were significantly improved by phosphorus application.

Respecting the effect of potassium humate, data show that seed quality was positively improved as affected by potassium humate application. Comparing with no potassium humate, potassium humate application increased protein (%) and yield as well as oil (%) and yield by about 5.12, 9.36, 1.6 and 20.26 %, respectively in the first season. Same trend was obtained in the second season. The positive effect of potassium humate on seed quality may be due to its effect on nitrogen and phosphorus content as well as seed yield as mentioned before, consequently increased protein and oil percentages and yields. These results are in accordance with those obtained by El-Shafey and Zen-El-Dein (2016).

As for the interaction, the data clearly show that seed quality of soybean plants did not respond to the interaction between treatments. In general, the soybean plants treated with NPK plus potassium humate under any tillage methods exhibited the greatest seed quality, while the plants without both of N, P and K as well as potassium humate under no or full tillage recorded the lowest ones.

Soil properties

Data of the effect of tillage system, NPK fertilization and potassium humate application on soil properties after soybean harvest are given in Tables 6 and 7. The results indicate that bulk density, soil available water was significantly affected by tillage system and potassium humate application, while these properties were improved under no tillage and potassium humate application. The soil reaction affected only by potassium humate only, where added potassium humate significantly decreased the pH values. Moreover, soil organic matter after harvest responded only to tillage treatments, where soil organic matter increased due to no tillage in comparison to traditional one. The promotive effect of reducing tillage processes on organic matter and water relations is mainly due to reducing soil mobilization resulted to no tillage caused soil become more compacted, accordingly improved soil organic matter and soil water relations (Moraru and Rusu, 2012). They added reducing tillage resulted in increasing the penetration resistance, consequently improved water relations. The beneficial effect of potassium humate on soil properties may be due to potassium humate contain decomposed anion acids and organic complex, e.g., carboxyl ($COOH^{-1}$) and phenols (OH^{-1}) groups which had positive effect on soil properties (Schnitzer, 1992). These results are in harmony with those obtained by Russa *et al.* (2011) and Mohamed and El-Hamed (2020) for tillage system, and Bhatti et asl. (2011) and Sarhan and Abd El-Gayed (2017).

Table 6. Response of pH, EC and organic matter to tillage system, NPK fertilization and potassium humate application.

Treatments			First season			Second season		
Tillage (A)	NPK (B)	Potassium humate (C)	pH	EC dS m^{-1}	OM %	pH	EC dS m^{-1}	OM %
No Tillage (T_1)	0.0	Without	7.65	1.18	1.96	7.73	1.26	2.02
	NP		7.64	1.17	1.95	7.75	1.24	2.01
	NK		7.65	1.18	1.94	7.72	1.26	2.02
	PK		7.64	1.17	1.96	7.75	1.25	2.01
	NPK		7.64	1.16	1.95	7.77	1.26	2.04
	mean		7.64	1.17	1.95	7.74	1.25	2.02
	0.0	With	7.54	1.16	1.94	7.65	1.25	2.00
	NP		7.54	1.15	1.96	7.63	1.25	2.03
	NK		7.55	1.17	1.96	7.66	1.24	2.04
	PK		7.54	1.16	1.94	7.62	1.27	2.03
	NPK		7.57	1.17	1.95	7.63	1.25	2.03
	mean		7.55	1.16	1.95	7.64	1.25	2.03
Mean			7.60	1.17	1.95	7.69	1.25	2.02
Full tillage (T_2)	0.0	Without	7.67	1.17	1.84	7.75	1.25	1.86
	NP		7.66	1.16	1.83	7.71	1.23	1.86
	NK		7.69	1.16	1.84	7.75	1.25	1.85
	PK		7.63	1.17	1.85	7.72	1.24	1.87
	NPK		7.66	1.16	1.86	7.73	1.25	1.87
	mean		7.66	1.17	1.84	7.73	1.24	1.86
	0.0	With	7.55	1.16	1.86	7.62	1.24	1.88
	NP		7.55	1.17	1.86	7.62	1.26	1.87
	NK		7.57	1.15	1.85	7.64	1.24	1.84
	PK		7.54	1.16	1.84	7.61	1.26	1.88
	NPK		7.53	1.17	1.84	7.62	1.24	1.89
	mean		7.55	1.16	1.85	7.62	1.25	1.87
Mean			7.61	1.16	1.85	7.68	1.25	1.87
Mean of NPK		0.0	7.61	1.17	1.90	7.69	1.25	1.94
		NP	7.60	1.16	1.89	7.68	1.25	1.92
		NK	7.60	1.17	1.87	7.68	1.25	1.90
		PK	7.59	1.16	1.88	7.67	1.25	1.91
		NPK	7.60	1.17	1.88	7.68	1.25	1.92
Mean of potassium humate		Without	7.65	1.17	1.90	7.74	1.25	1.94
		With	7.55	1.16	1.90	7.63	1.25	1.95
L.S.D at 0.05								
A			N.S.	N.S.	0.04	N.S.	N.S.	0.04
B			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C			0.06	N.S.	N.S.	0.07	N.S.	N.S.
AB			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
AC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
BC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
ABC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 7. Response of bulk density, soil available water and wilting point to tillage system, NPK fertilization and potassium humate application.

Treatments			First season			Second season		
Tillage (A)	NPK (B)	Potassium humate (C)	Bulk density ($g\ cm^{-3}$)	Soil available water (%)	Wilting point (%)	Bulk density ($g\ cm^{-3}$)	Soil available water (%)	Wilting point (%)
No Tillage (T_1)	0.0	Without	2.24	21.13	21.52	2.22	20.89	21.19
	NP		2.25	21.26	22.23	2.23	20.95	22.13
	NK		2.26	21.17	22.15	2.22	20.78	21.93
	PK		2.24	21.25	21.62	2.23	20.71	21.42
	NPK		2.25	21.19	21.75	2.22	20.63	21.43
	mean		2.25	21.20	21.85	2.22	20.79	21.62
	0.0	With	2.27	22.62	20.36	2.24	22.03	20.07
	NP		2.27	22.68	20.15	2.25	22.16	20.01
	NK		2.26	22.70	20.40	2.25	22.02	20.19
	PK		2.26	22.77	20.46	2.25	22.01	20.15
	NPK		2.27	22.73	20.17	2.24	22.11	19.96
	mean		2.27	22.70	20.31	2.25	22.07	20.08
Mean			2.26	21.95	21.08	2.24	21.43	20.85
Full tillage (T_2)	0.0	Without	2.21	20.25	20.82	2.20	20.01	20.64
	NP		2.22	20.51	20.87	2.20	20.21	20.43
	NK		2.21	20.49	20.82	2.19	20.24	20.54
	PK		2.22	20.52	20.81	2.20	20.17	20.64
	NPK		2.21	20.48	20.44	2.19	20.29	20.53
	mean		2.21	20.45	20.75	2.20	20.18	20.56
	0.0	With	2.24	21.66	19.51	2.22	21.41	19.23
	NP		2.24	21.69	19.77	2.22	21.39	19.50
	NK		2.23	21.73	19.75	2.22	21.18	19.56
	PK		2.24	21.59	19.70	2.22	21.25	19.48
	NPK		2.24	21.61	19.73	2.23	21.31	19.45
	mean		2.24	21.66	19.69	2.22	21.31	19.44
Mean			2.23	21.05	20.22	2.21	20.75	20.00
Mean of NPK		0.0	2.24	21.42	20.55	2.22	21.09	20.28
		NP	2.24	21.49	20.31	2.22	21.13	20.06
		NK	2.23	21.20	20.30	2.22	20.91	20.05
		PK	2.24	21.44	20.18	2.22	21.13	19.91
		NPK	2.24	21.39	20.33	2.22	21.07	20.07
Mean of potassium humate		Without	2.23	20.83	21.30	2.21	20.49	21.09
		With	2.26	22.18	20.00	2.24	21.69	19.76
L.S.D at 0.05								
A			0.01	0.42	0.53	0.01	0.36	0.50
B			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C			0.01	0.13	0.15	0.01	0.12	0.14
AB			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
AC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
BC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
ABC			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

CONCLUSION

The results indicated that no tillage method resulted in soybean quality and quantity at par to those under traditional one, which means to save the tillage cost. Additionally, N, P and K as well as potassium humate application increased soybean productivity. Also, no tillage and potassium humate application improved soil reaction, organic matter, bulk density, soil available water and wilting point after soybean harvesting. Therefore, it could be recommended to grow soybean plants under no tillage and supplied the plants with 72, 33 and 95 kg N, P and K ha^{-1} as well as added 24 kg ha^{-1} potassium humate as soil application to maximize soybean productivity and minimizing its costs.

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استجابة نبات فول الصويا وخواص التربة إلى التسميد النيتروجيني والفوسفاتي والبوتاسي وكذلك أضافة المواد الهيومية تحت نظم حرث مختلفة

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أقيمت تجربة حقلية فى موسمى النمو 2019 ، 2020 بمحطة البحوث الزراعية بسدس- مركز البحوث الزراعية- محافظة بنى سويف لدراسة تأثير التسميد بالنتروجين والفوسفور والبوتاسيوم واضافة المواد الهيومية تحت نظامى حرث (بدون حرث والحرث التقليدى) على انتاجية فول الصويا كما ونوعا وقد استخدم تصميم القطع المنشقة في أربع مكررات، حيث نفذت طرق الحرث فى القطع الرئيسية، كما وضع التسميد بعناصر النيتروجين والفوسفور والبوتاسيوم (بدون، نيتروجين + فوسفور، نيتروجين + بوتاسيوم، فوسفور + بوتاسيوم، نيتروجين + فوسفور + بوتاسيوم بمعدل 72، 75، 115 كجم ن، فو2أ5، بو2أ / هكتار) فى القطع المنشقه، بينما أضيفت معاملات المواد الهيومية (24 كجم / هكتار هيومات بوتاسيوم اضافة أرضية، بدون المواد الهيومية) فى معاملات القطع منشقة المنشقة: وكانت أهم النتائج المتحصل عليها كما يلى:- لم تؤثر طرق الحرث على كل صفات النمو والمحصول ومكوناته وجودة البذور لفول الصويا، ما عدا عدد العقد الجذرية للنبات، الوزن الجاف للعقد الجذرية للنبات حيث أدى عدم الحرث الى زيادتها مقارنة بالحرث التقليدى. أدى التسميد بالعناصر الكبرى (ن، فو، بو) الى زيادة كل صفات النمو (عدد العقد الحذرية للنبات، وزن العقد الجذرية للنبات، طول النبات)، مكونات المحصول (عدد القرون للنبات، عدد البذور فى القرن، وزن المائة حبة)، محصول البذور والقش، تركيز عناصر النيتروجين والفوسفور والبوتاسيوم فى البذور والقش ونسبة ومحصول كلا من البروتين والزيت فى البذور مقارنة بمعاملة الكنترول، وكان اضافة الفوسفور هو الأكثر تأثيرا. أدى اضافة هيومات البوتاسيوم أرضا الى زيادة الصفات السابقة مقارنة بمعاملة عدم اضافة هيومات البوتاسيوم. ادي عدم الحرث وكذلك اضافه المواد الهيومية الي تحسين حموضه التربه والماده العضويه وكثافه التربه الظاهريه والماء الصالح ونقطه الذبول بعد الحصاد.أظهرت نتائج التداخل بين المعاملات على أن أعلى محصول لفول الصويا كما ونوعا كان لمعاملة التسميد بالنيتروجين والفوسفور والبوتاسيوم مع اضافة حامض الهيومك تحت نظام الحرث التقليدى أو عدم الحرث (زراعة مباشرة). ويمكن من نتائج الدراسة التوصية بتسميد نبات فول الصويا بمعدل 72، 75، 115 كجم من عناصر ن، فو2أ5، بو2أ مع اضافة 24 كجم هيومات البوتاسيوم قبل الزراعة مع عدم الحرث وذلك بهدف تعظيم الانتاجية مع جودة البذور وتقليل تكلفة الحرث.