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EFFECT OF POTASSIUM AND FOLIAR NUTRITION WITH HUMIC ACID ON GROWTH AND YIELD OF *SORGHUM BICOLOR* (L.) *MEONCH*

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Abstract

A factorial experiment within split-plots was applied according to Randomized Complete Block Design (RCBD) with three replications. This study has been done in Diyala governorate, Al-Muqdadia, Abi-Sayda region, during the Summer Season in 27/7/2017. The soil in which *Sorghum bicolor* (L.) *Meonch* were grown was a sandy clay loam . The aim of this study is to know the effect of Potassium addition in the form of K_2SO_4 (K % 41.5) to the soil with three levels 0, 100 and 120 kg K ha^{-1}, which occupied the main-plots and the effect of foliar nutrition with humic acid including three levels 0, 1 and 2 ml l^{-1}, which occupied the sub-plots on the growth and yield of *Sorghum bicolor* (L.) *Meonch* "Rabih".

The results showed that the addition of Potassium with the concentration 120 kg K ha^{-1} led to increasing plant height, leaf area, weight of 1000 grains, and total yield, they reached 216.06 cm., 69.20 dcm^2 $plant^{-1}$, 33.95g, 16.14ton ha^{-1} respectively, as compared with control treatment. While spraying humic acid with the concentration 2 ml l^{-1} led to increasing plant height, stem diameter, dry weight, head length, grains weight per head, net weight of head, total yield, and chlorophyll guide, they reached 210.20 cm, 2.99 cm, 213.64 g $plant^{-1}$, 31.65 cm, 134.41 g, 82.47 %,16.42 ton ha^{-1} and 55.62 SPAD respectively, as compared with the control treatment. While the interpenetration of 120 kg K ha^{-1} × 2 ml l^{-1} showed a significant effect in most attributes.

Key words : Potassium, Foliar Nutrition of Humic acid, *Sorghum bicolor* (L.) *Meonch*.

Introduction

Sorghum bicolor (L.) *Meonch* belongs to the Poaceae. It is considered as an important source of food for a large number of the world's population and it is grown for the purpose of obtaining mineral-rich food and seasonal grains. It is an important summer crop since it can be considered as a resistant crop to drought (Amsalu and Endashaw, 1998). Studies have been conducted on the status of potassium found in Iraqi soils (Al-Rubaie, 1995; Al-Obaidi, 1996; Al-Samarrai, 1996; Al-Rubaie, 1998; Al-Melik, 2002). These studies showed that Iraqi soils are rich in potassium, for most arid and semi-arid soils, but their release is slow and does not meet the needs of many agricultural crops, especially under dense farming conditions or high-demand crops for this element (Al-Zubaidi, 2001). It is found that the plant's need for potassium exceeds its need for any other nutrient except the nitrogen, and may exceed it at some stages of growth, although this element does not enter the composition of any organic material in the plant tissues. It is found in the form of dissolved organic salts or salts of organic acid or in the form of free ion K^+ which is the image absorbed by the plant from the soil solution. (Awad, 1987; Maathius and Sanders, 1996). Leaf nutrition with humic acid reduces the energy required for the transfer of elements' ions within the plant, as well as providing the plant with the nutrients that the roots can not provide during the critical stages of growth. In addition, leaf fertilizers are added to the plant to reduce the lack of nutrients by spraying the solutions on the green parts and they are faster than land fertilization (Al-Emam and Al-Ahmar, 2003). The humic materials are known as complex organic materials, which are produced by the decomposition of plants and animals. These substances are mainly composed of humic acid, folic acid and hummins. These substances play a major role in soil fertility and plant nutrition since they increase permeability of cellular membranes, cell division, elongation of cells, production of plant enzymes and stimulation of intracellular vitamins

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(Pettit, 2003). The aim of this study is to show the best concentration of potassium and humic acid and the best combination between them to achieve the best growth and production of *Sorghum bicolor* (L.) *Meonch*.

Materials and Method

A field experiment was carried out in the summer season, specifically in 27/7/ 2017 in the province of Diyala, Al-Muqdadiya, Abi-Sayda, about 60 km Northeast of the city of Baquba, to study the effect of the addition of potassium and leaf nutrition on the growth and production of *Sorghum bicolor* (L.) *Meonch* class "Rabih".

A factorial experiment within split-plots was applied according to Randomized Complete Block Design (RCBD) with three replications. The area of the experimental unit was (2 × 2) m^2, a longitudinal lines were opened in each experimental unit with four lines and the distance between lines was 50 cm, while the distance between holes was 20 cm. Each experimental unit had 4 lines. About 1 m distance has been left to avoid overlap between experimental units. Table 1 shows some chemical and physical properties of soil before planting.

Table 1: Shows some chemical and physical properties of the soil of study before planting.

Character		Value	Unit
Soil pH		7.11	-
Electrical Conductivity EC		5.33	d S m^{-1}
Organic matter		18.00	$g.kg^{-1}$.soil
Available Nitrogen		28.12	mg kg^{-1} soil
Phosphorus Available		10.74	mg kg^{-1} soil
Potassium Available		378.40	mg kg^{-1} soil
Soil separators	Sand	572.10	g kg^{-1} soil
	Gluten	180.10	g kg^{-1} soil
	Clay	247.80	g kg^{-1} Soil
Texture		sandy clay loam	

* The analysis was done in the Faculty of Agriculture / University of Diyala

Soil Analysis

Random samples were taken from different places of the soil from 0 to 30 cm before planting and fertilization. They were dried, grinded and passed through a 2 mm diameter sieve. The samples were then thoroughly mixed for homogenization and a particular weight was taken for analysis. Chemical analysis included available (Nitrogen, Phosphorus, Potassium), organic matter, electrical conductivity EC, soil pH, and physical analysis included soil texture analysis. The volumetric distribution of the soil separators is estimated by the pipette method (Page *et al*., 1982). The study included two factors: the addition of Potassium in the form of K_2SO_4 (K 41.5 %) as a source of Potassium to the soil with three levels 0, 100 and 120 kg K ha^{-1}, which occupied the main plots, and the leaf nutrition of humic acid with three levels 0, 1, and 2 ml l^{-1}, which occupied the sub-plots with 8 t ha^{-1} of urea in each experimental unit. The first addition was after 21 days of germination and the second one was before flowering.

The calcium superphosphate fertilizer was added in one batch in the planting day with 16 t ha^{-1} in each unit. The insect of corn stalk Sesamia cretica was combed with 10% of granulator diazinon by adding a tip of teaspoon on the developing plant's top when it was in 3-4 leaves, with leaving one plant per hole.

The Studied Traits

They were calculated on the basis of individual plant as an average of 5 protected plants taken from the intermediate lines of each experimental unit.

Number of days of planting up to 100% flowering: This characteristic was determined by observing the flowering of 100% of plants in the two central lines of each experimental unit and recording that date, and then counting the number of days of planting up to 100% flowering.

Plant height (cm): The length of the plant was measured by a strip from the soil surface to the top of the plant (Kirby and Atkins, 1968, Kambal and Webester, 1965 and House, 1985).

Stem diameter (cm): The stem diameter was measured from the center of the first salinity above the surface of the soil by means of nylon measuring tape, noting that the leaf sheath was removed before the measurement. The arithmetic relationship between the circumference and the diameter was obtained to extract the diameter of the stem:

circumference (cm) = diameter × 3.14 (Quinby, 1963).

Number of leaves : The leaves in the main stem of the plant were calculated from the first green leaf close to the surface of the soil up to the top of the plant with counting the leaves that die at the base of the leg or those which are buried due to field operations (Kambal and Webster, 1966).

The leaf area (dsm2 Plant^{-1}) : It was measured at the end of the growth season by counting the average area of leaves for five plants which were taken from the middle lines of each experimental unit and at the stage of 100% flowering using the following formula:-

Leaf area = height × maximum width × 0.75 (Liang *et al*., 1973)

The dry weight of the vegetative plant (g plant^{-1}) : The dry weight of the vegetative plant was calculated after physiological maturity. Five plants were cut from the middle lines of each experimental unit about 5 cm from the surface of the ground (Al-Ansari, *et al*., 1980), they were placed in perforated paper bags and then left to dry on the air for two weeks. Then the weight has been recorded to extract the average of the five plants (Abu Dhahi, 1989).

Components of the product

Head length (cm): The distance between the base of the head and its top of five plants (House, 1985, Kambal and Webester 1966).

Head diameter (cm): The head diameter was measured at the widest point of the five studied heads by a measuring tape made of nylon. The adopted mathematical relationship between the circumference and diameter to extract the diameter was the following:

Head circumference (cm) = diameter × 3.14 (House 1985)

Head weight (g): The average weight of five heads was calculated by a sensitive balance for each experimental unit. (Kambal and Webester 1956; House 1985)

Grain weight per head (g) : The average of five headers was calculated by a sensitive balance for each experimental unit.

Weight of 1000 grains(g): 500 grains of each experimental unit were counted and weighed and multiplied by 2.

Net weight of heads (%) : They were calculated from the following formula after drying the grains to the degree that allows them to be separated from the heads:

$$\text{Net weight \%} = \frac{\text{Grain weight in the head}}{\text{Full head weight}} \times 100 \text{ (Quinby, 1963)}$$

Total yield (ton ha^{-1}) : The total quantity of yield in each experimental unit was calculated on the basis that the total plant density is (100000 plants.ha^{-1}) and the total yield was calculated through the following formula**:**

Total yield (tons ha^{-1}) = average yield of one plant (head weight) × 100000

Chlorophyll Guide (SPAD unit) in the leaf: Chlorophyll was measured in the leaves after 80 days of cultivation using the SPAD-502 meter in the field directly (Felix, *et al*., 2000).

Table 2: Effect of Soil addition of Potassium and Leaf Nutrition with Humic Acid and their Overlap in Vegetative Growth Indicators of *Sorghum* bicolor (L.) *Meonch*.

Potassium concentration kg K ha^{-1}	Humic concen-tration ml l^{-1}	The No. of days of planting up to 100% flowering	Plant height (cm)	Stem diameter (cm)	Number of leaves (leaf plant^{-1})	Leaf area (Dsm^2 plant-^{1})
0	0	25.15 c	180.20 c	2.82	15.00 c	57.15 b
	1	40.00 bc	190.53 c	2.89	15.22 c	57.60 b
	2	45.55 bc	200.60 b	2.90	15.91 bc	57.89 b
100	0	50.00 b	206.20 b	2.71	16.47 b	61.05 b
	1	60.00 b	209.00 ab	2.65	16.50 b	62.07 b
	2	72.50 ab	211.30 ab	3.00	16.73 b	68.96 ab
120	0	75.92 ab	213.90 ab	2.66	16.75 b	67.43 ab
	1	84.44 ab	215.60 ab	2.62	17.08 ab	67.74 ab
	2	95.00 a	218.70 a	3.07	17.65 a	72.44 a
L.S.D (0.01)		24.70	2.29	NS	089	7.29
Average of potassium effect	0	36.90 c	190.44 c	2.87	15.37 b	57.54 c
	100	60.83 b	208.83 b	2.79	16.56 a	64.02 b
	120	85.12 a	216.06 a	2.78	17.16 a	69.20 a
L.S.D (0.01)		18.18	6.68	NS	0.51	4.21
Average of humic acid effect	0	50.35 b	200.10 b	2.73 b	16.07 b	61.87 b
	1	61.48 ab	205.04 ab	2.72 b	16.26 b	62.47 b
	2	71.01 a	210.20 a	2.99 a	16.76 a	66.43 a
L.S.D (0.05)		13.19	6.18	0.24	0.47	3.89

Results and Discussion

From Table 2, it is noted that the treatment to which the potassium has been added with the concentration of 120 Kg K ha^{-1} was significantly higher in most indicators of vegetative growth, which is, the number of days of cultivation up to 100% flowering, plant height and leaf area. This concentration gave the highest average, it reached 85.12 %days, 216.06 cm, and 69.20 dsm^2 plant^{-1}, as compared with the treatment of100 Kg K ha^{-1} and the comparison treatment which gave the lowest average. While the concentration of 100 and 120 kg K ha^{-1} exceeded significantly in the number of leaves giving the highest average of 16.56 and 17.16 leaf plant^{-1}, compared with the comparison treatment, which gave the lowest average of 15.37 leaf plant^{-1} with an increase of 7.74% and 11.64%, respectively. The positive effect of potassium in increasing vegetative growth indicators may be due to the role of potassium in activating the action of oxytin and gebrilins which have an effective role in the process of division and elongation of plant cells, which is positively reflected in longitudinal growth, accelerating the 100% flowering days, increasing plant height and leaf area when added in the solid form (IPI, 2000).

The results of the same table showed no significant differences in the different levels of potassium for the stem diameter. Concerning the effect of spraying the humic acid with the concentration of 2 ml l^{-1}, it was significantly higher in the average number of days from planting to 100% flowering and plant height. The highest average was 71.01% days and 210.20 cm compared with the comparison treatment. While the concentration of 2 ml l^{-1} exceeded in stem diameter, number of leaves and the leaf area, giving the highest average of 2.99 cm, 16.76 leaf plants^{-1} and 66.43 dsm^2 plants^{-1} compared with the comparison treatment. This is due to the positive effect of humic acid on plant growth by increasing permeability of cellular membranes, stimulating enzymatic reactions, improving cell division, elongating cells, increasing plant enzyme production and stimulating intracellular vitamins (Pettit, 2003).

The binary interaction between the soil addition of potassium and spraying with the humic acid significantly affected the number of days from planting up to 100% flowering, plant height, number of leaves and leaf area, since the binary interaction 120 Kg K ha^{-1} × 2 ml l^{-1} gave the highest average, it reached 95.00% days, 218.70 cm, 17.65 leaf Plant^{-1} and 72.44 dsm^2 Plant^{-1} compared with the comparison treatment, which gave the lowest average of 25.15% days, 180.20 cm, 15.00 leaf Plants^{-1} and 57.15 dsm^2 plant^{-1} and an increase of 277.73%, 21.36%, 17.66% and 26.75%, respectively, this may be due to the effect of both potassium and humic acid alone, which increased during the overlap. The results showed no significant differences in the binary interaction between different levels of soil addition of potassium and spraying with humic acid in the diameter of the stem.

Table 3 shows that the treatment to which the potassium has been added significantly affected the average of head weight and grains weight per head. The concentration 120 kg K ha^{-1} gave the highest average of 165.34 g and 143.00 g compared with the comparison treatment which gave the lowest average of 129.19 g and 107.02 g with an increase reached 27.98% and 33.61%, respectively, while the results showed no significant differences in the concentration of 100 kg K ha^{-1} in the attributes mentioned above which gave an average of 145.61 g and 120.45 g respectively. This is due to the fact that the potassium fertilizer works to increase the content of carbohydrates manufactured in the process of photosynthesis, which increases the leaf area in addition to its effect in improving the performance of plant hormones, which directly enter the expansion and division of cells and their elongation (table 2, Abu-Dhahi and Al-Yunis, 1988). When the amount of potassium which is added to the soil is within the actual need of the plant and in the suitable time this will increase vegetative growth and the efficiency of the process of photosynthesis of the leaves, resulting in an increase in the number of leaves and the surface area because it is the main center for food manufacturing and metabolism which reflected on the weight of the head and his grain (Gardner *et al*., 1990, Heckman and Kamprath, 1995).

Table 3: Effect of soil addition of potassium and leaf nutrition with humic acid and their overlap in some of the quantitative components of the yield of *Sorghum bicolor* (L.) *Meonch*

Potassium concentration kg K ha^{-1}	Humic concen-tration ml l^{-1}	Dry Weight (g plant^{-1})	Head length (cm)	Head diameter (cm)	Head weight (g)	Weight of grains in head (g)
0	0	170.07	30.00	5.62	123.87	97.70
	1	183.33	30.77	5.99	125.33	106.73
	2	211.35	31.25	6.34	138.39	116.65
100	0	186.15	30.16	6.19	139.90	111.46
	1	187.08	30.91	6.22	140.49	118.51
	2	193.75	31.54	6.27	156.46	131.38
120	0	169.96	30.27	5.77	161.61	133.54
	1	175.08	31.12	6.31	162.27	140.25
	2	235.83	32.16	6.44	172.16	155.21
L.S.D (0.01)		NS	NS	NS	NS	NS
Average of potassium effect	0	188.25	30.67	5.98	129.19 b	107.02 b
	100	188.99	30.87	6.22	145.61 ab	120.45 ab
	120	193.62	31.18	6.17	165.34 a	143.00 a
L.S.D (0.01)		NS	NS	NS	22.19	15.37
Average of humic acid effect	0	175.39 b	30.14 b	5.86	141.79	114.23 b
	1	181.83 b	30.93 a	6.17	142.69	121.83 ab
	2	213.64 a	31.65 a	6.35	155.67	134.41 a
L.S.D(0.01)		23.34	0.74	NS	NS	14.22 .05

The results showed that the different levels of potassium did not significantly affect on the average of dry weight, head length and diameter. Concerning the effect of spraying humic acid, the results showed that the concentration of 2 ml l^{-1} was significantly higher in the average of dry weight of 213.64 g plant^{-1}, compared with the concentration of 1 ml l^{-1}, and the comparison treatment which gave the lowest yield of 181.83 and 175.39 g plants^{-1}, with an increase of 17.74% and 21.80%, respectively. The concentrations of 2 and 1 ml l^{-1} were significantly superior in the average of head length, giving the highest average of 31.65 and 30.93 cm compared with the comparison treatment which gave the lowest average of 30.14 cm and an increase of 5.00% and 2.62%, respectively. While the results showed the superiority of the concentration of 2 ml l^{-1} in grains weight of head, giving the highest average of 134.41 g, compared with the comparison treatment, which gave the lowest average of 114.234 g, with an increase of 17.66% .While there were no significant differences in the same attribute in the concentration of 1 ml l^{-1}, giving an average of 121.83 g. This was due to the role of the humic acid in increasing the vegetative growth indices represented in plant height, number of leaves and leaf area (table 2), consequently, increasing the photosynthesis processes that goes to the new sites of reproduction in the vegetative stage of the plant, including flowers, increases the fertility rate, which is reflected in an increase in dry weight and head length of the plant as well as the grain weight per head (Paul and Foyer, 2001). Table 3 shows no significant differences in the average of head diameter and head weight when spraying different levels of the humic acid, as well as the binary interaction between the soil addition of potassium and spraying of humic acid in all quantitative yield indicators.

Table 4 shows that the addition of different potassium levels significantly affected on the average weight of 1000 grains and the percentage of the head net weight, The concentration 120 Kg K ha^{-1} gave the highest average of 33.95 g and 84.47%, compared with the comparison treatment. While the results showed that the concentrations of 100 and 120 Kg K ha^{-1} outplayed significantly in the average of total yield and chlorophyll guide in the leaves, they gave the highest average of 14.88 and 16.14 tons ha^{-1}, 54.38 and 55.57 SPAD compared with the comparison treatment which gave the lowest average 12.83 tons ha^{-1} and 49.39 SPAD with an increase of 15.97%, 25.79%, 11.1% and 12.51% respectively. The linear increase in the weight of 1000 grains, the total yield and chlorophyll guide in the leaf with increasing of the soil application of the potassium fertilizer in addition to the superiority of the concentration 120 kg K ha^{-1} belongs to the linear increase in the soil application treatments and the superiority of the treatment of 120 Kg K ha^{-1} in the characteristics of plant height, leaf area, head weight and grains weight per head (Tables 2 and 3), this is the reason for this significant increase in the weight of 1000 grains and the total yield of these treatments. In addition, the effect of potassium is important in increasing the efficiency of the process of photosynthesis, consequently increasing the products of this process which precipitate as a dry substance in the plant parts (Al-Falahi, 2005, Shirin *et al*., 2010).

Concerning the effect of spraying humic acid, the results showed that the concentration of 2 ml l^{-1} was significantly higher in the weight of 1000 grains and the total yield, giving the highest average of 32.68 g and 16.42 tons ha^{-1}, compared with the comparison treatment which gave the lowest average 29.49 g, and 13.17 tons ha^{-1} with an increase of 10.81%, and 24.67%, respectively. While the results showed the existence of significant differences in the concentration of 1 ml l^{-1} in the average

Table 4: Effect of soil addition of potassium and leaf nutrition with humic acid and their overlap in some of the components of the yield of *Sorghum bicolor* (L.) *Meonch*

Potassium concentration kg K ha^{-1}	Humic concen-tration ml l^{-1}	Weight of 1000 grains (g)	Net Weight of head(%)	Total Yield (ton ha^{-1})	Chlorophyll Guide in leaves (SPAD unit)
0	0	25.87 c	78.69 b	11.38 b	42.95 c
	1	27.40 bc	80.13 ab	12.53 b	50.91 b
	2	30.44 bc	80.23 ab	14.58 b	54.32 ab
100	0	29.97 b	73.68 b	13.98 b	53.68 ab
	1	31.22 b	83.81 ab	14.54 b	53.93 ab
	2	31.95 ab	83.29 ab	16.14 a	55.53 ab
120	0	32.65 ab	84.18 ab	14.16 b	54.05 ab
	1	33.57 ab	85.35 a	15.72 a	55.64 a
	2	35.65 a	83.90 ab	18.56 a	57.03 a
L.S.D (0.01)		4.31 .01	5.91	3.39	4.69 .01
Average of potassium effect	0	27.9 c	79.68 b	12.83 b	49.39 b
	100	31.04 b	80.26 b	14.88 a	54.38 a
	120	33.95 a	84.47 a	16.14 a	55.57 a
L.S.D (0.01)		2.84 .01	3.41	1.96	2.71 .01
Average of humic acid effect	0	29.49 c	78.85 b	13.17b	50.22 b
	1	30.73 b	83.10 a	14.26 b	53.49 a
	2	32.68 a	82.47 a	16.42 a	55.62 a
L.S.D(0.05)		0.76	3.41	1.96	2.71 .01

of the same qualities mentioned above, giving the highest average of 30.73 g and 14.26 tons ha^{-1}, compared with the comparison treatment, giving the lowest average of 29.49 g and 13.17 tons respectively. The results showed that the concentrations of 1 and 2 ml l^{-1} outplayed significantly in the percentage of the chlorophyll guide the in the leaf and the net weight. They showed the highest average of 83.10%, 82.47%, 53.49 % and 55.62 SPAD respectively, compared with the comparison treatment which gave the lowest average of 78.85% and 50.22 SPAD with an increase of 5.38%, 4.59%, 6.51% and 10.75%, respectively, the superiority of the concentration 2 ml l^{-1} of humic acid in the leaf area and head length (table 2 and 3) effectively contributed in providing the growing grains with their need of nutrition which reflected positively on their weight. This concentration also superimposed in the number of leaves and grains weight per head (table 2 and 3) and also contributed in increasing the weight of 1000 grains and the total yield. The results showed in table 4 that there was a significant effect in the interaction between the study factors in most of the yield components in the experiment. The binary interaction 120 kg K ha^{-1} × 2 ml l^{-1} gave the highest average in the attribute of 1000 grains, it was 35.65 g, compared with the binary interference 100 kg K ha^{-1} and 100 kg K ha^{-1} × 1ml l^{-1} and the comparison treatment, giving an average of 29.97, 31.22 and 25.87 g with an increase of 18.95%, 14.18% and 37.80%, respectively. Concerning the attribute of 1000 grains, the results showed the superiority of the binary interaction 100 kg K ha^{-1} × 0 ml l^{-1} and 100 kg K ha^{-1} × 1 ml l^{-1} giving the highest average of 29.97 and 31.22 g, compared with the comparison treatment which gave less average reached 25.78 g with an increase of 15.84% and 20.68%, respectively. The results also showed the existence of high significant effects in the attribute of chlorophyll guide in the binary interaction 120 kg K ha^{-1} x 1 ml l^{-1} and 120 kg K ha^{-1} × 2 ml l^{-1}, they gave the highest average which reached 55.64 and 57.03 SPAD compared with the binary interactions 0 kg K ha^{-1} × 0 ml l^{-1} and 0 kg K ha^{-1} × 1 ml l^{-1}, they gave the lowest average which reached 42.95 and 50.91 SPAD with an increase reached 29.54%, 9.29%, 32.78%, 12.02% respectively. While the results of the chlorophyll guide in eaves showed no significant effects in the binary interaction 0 kg K ha^{-1} × 2 ml l^{-1}, 100 kg K ha^{-1} × 0 ml l^{-1}, 100 kg K ha^{-1} × 1 ml l^{-1},100 kg K ha^{-1} × 2 ml l^{-1}, 120 kg K ha^{-1} × 0 ml l^{-1}, they gave the highest average which reached 54.32, 53.68, 53.93, 55.53, 54.05 SPAD, respectively.

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