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Effect of Urea and Nano-Nitrogen Fertigation and Foliar Application of Nano-Boron and Molybdenum on some Growth and Yield Parameters of Potato

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Abstract : **Investigating the effect of urea and nano-nitrogen fertigation and foliar application of nano B and Mo on growth and yield of potato Solanum tuberosum L. [Rivera-A]. The study was conducted in a private farm located in the Al-Taleah area - Babylon governorate. The experiment consisted of (12) treatments consisting of separated fertigation of nano nitrogen (25% N) and urea (46% N), single treatments of leaf spraying of nano Mo (5%), Nano B (9%), nano-binary combinations (Mo+B) and (U+ Nano Mo), (U+Nano B), Nano (N+Mo), Nano (N+B), and tricombination treatments of (U+Mo+B), Nano (N+Mo+B) additional to the control treatment. Randomize Complete Block Design (RCBD) and one way simple experiment with three replicates. Fertilizers were applied at levels of 40 liters h-1 of Nano-N fertilizer (25% N) and 300 kg h-1 urea fertilizer (46% N). They were sprayed early in the morning after (40) days after planting four times. Two weeks is the period between an application and another according to the recommendation of (1) kg h-1 nano-fertilizer of (B) and (500) g h^{-1} of Mo. Fertilizers were injected and sprayed at (10, 20, 30 and 40)% of the total amount of the fertilizer were applied as the first, second, third and fourth applications, respectively. Some growth traits were tested including the chlorophyll content in the leaves, the total dry vegetative yild, the soft tubers yield, and the biological yield, proteins and ascorbic acid yield compared to the control (spray water only). The results of the Duncan test showed a significant increase in most of the studied traits of nano-tricombination (N+Mo+B) in the fresh tubers yield, dry vegetative yield , the biological yield, starch yield ,the total protein and ascorbic yield (37.53, 1.799, 8.138,4.152 , 481.3and 653.8 meg ha^{-1}) respectively .compare to control (21.58 , 0.890, 4.463 ,2.323 , 366.1 and 215.5 meg ha-1) respectively.**

Keywords: **potato, fertilizer, fertigation, nano fertilizers, protein, ascorbic acid.**

I. INTRODUCTION

In recent years, researchers have tended to study several modern techniques in the agricultural field, particularly the possibility of using nanotechnology to improve the fertilizer use efficiency towards the design and development of so-called nano fertilizers (NF) [1,2]. Composites and molecules whose lengths range from (1-100) nanometers, for one dimension as minimally, called nanomaterials (NMs) [3,4]. These nanoparticles are characterized by their small size and large specific surface area, making them be ideal materials in the manufacture of fertilizers called smart fertilizers after encapsulation with polymers or chelated to be slow release to suit the stages of plant [5,6].

Nano fertilizers are important in increasing the efficiency of nutrients, having a higher yield, better quality, and safer environment. It reduces soil contamination as well as potential adverse effects when conventional mineral fertilizers are applied [7-9]. Nano fertilizers (NF) are more efficient and effective than conventional fertilizers because of their positive effects on the quality of food crops, reduce stresses that occur to the plant, small applied quantities and costs, their fast of absorption by plant cells and penetration of cells and the fats of transport and representation within plant tissue [7-11]. Fertigation is the process of fertilizer application with irrigation water in various irrigation systems such as drip or sprinkler irrigation. Therefore, fertilizers are distributed in the soil by irrigation water [12]. This method is one of the best ways to manage water and nutrients and more efficient for food as well as to maintain soil fertility. It is an effective method by reducing the cost when fertilizer application. One of the most important benefits of this technology is the application of nutrients in proportion to the growth of the crop to meet the nutritional needs and high accuracy and then achieve a high yield of the crop [12].

Fertigation reduces the loss and washing of applied nutrients by comparing the amount of water applied and the movement of moving elements within the soil. The availability of the applied nutrients is high enough to suit the absorption process. One of the objectives of fertilized irrigation is to reduce the negative effects on the environment caused by the high washing of fertilizers outside of the root zone [13,14]. In the fertilization process, there is a high capacity of the fertilizers to move with irrigation water penetrating into the soil so that the fertilizer is homogeneous after its complete solubility in water and is not sedimentable [14,15].

Foliar Nutrition means the application of the nutrients needed by the plant by spraying their solutions on the vegetative part within certain concentrations and in time so that the plant can absorb it through the stomata of the leaf or through the cell walls and membranes to participate in the vital plant processes. This increases the vegetative and qualitative qualities to avoid conditions that reduce the availability of plant nutrients in the soil [16].

Potato, Solanum tuberosum L. belongs to the Solanaceae family, is one of the most important foods and vegetable crops in terms of nutritional importance. It is in the fourth place as a strategic and economic crop after wheat, rice, and maize [17-19]. It is one of the major crops in the diet of the entire world population and is also used as animal feed [20]. It is also an energy-rich food that is a source of proteins, carbohydrates, starch, and major amino acids as well as minerals that are important for human nutrition [21]. Therefore, this study was aimed to investigate the effect of urea and nano-nitrogen fertigation and the foliar application of nano molybdenum and nano-boron on some growth and yield traits of potato.

II. Material and Methods

This field trial was conducted in the Al-Husayniyah / Al-Taliah district/ Babylon province during the autumn of 2018. The texture of field soil was silty clay loam as its chemical and physical properties presented in Table (1). The aim of this study was to investigate the effect of urea fertilizer, nano-nitrogen fertigation and sprayed of nano-molybdenum and boron on the growth and yield of the Riviera-A variety of potato.. The experiment included 12 treatments, separated fertigation of nano-nitrogen (25% N) and urea (46% N), separated foliar application of nano molybdenum (5% Mo), Nano Boron (9% B), nano dual combinations treatments of nano (Mo+B) and (U+Mo), (U+B), Nano (N+Mo), Nano (N+B), and tricombinations treatment of (U+Mo+B), Nano (N+Mo+B) in addition to control treatment table (2). in a simple one-way experience using with designed according to the (RCBD) with three replications.

The potato tubers (Solanum tuberosum L.) were planted on September 20th 2018. The planted potato tubers were produced during the spring and stored at (4)$^{\circ}$C and refrigerated warehouses till usage. Outwardly healthy tubers were selected after transplanting and (0.2)m were left in between. The planting process was carried out by opening an incision with a depth of (0.10)m from the area above the center and along the line. The hoeing was done manually whenever needed to get rid of the bush growing with the crop. After 40 days of planting, nitrogen fertilizer of both urea and nano-fertilizer was applied four times (10, 20, 30 and 40%) for each time of the total amount of fertilizer (300) kg h^{-1} of (urea) and (40) Liters h^{-1} of nano-nitrogen were fertigation applied. Fertilizers of nano-boron (9)% and nano-Molabedioum (5)% were sprayed after equalizing their weight to balance the same concentrations of nano fertilizers in addition to the water treatment only. Foliar application was applied early in the morning four times with concentrations of (10, 20, 30 and 40%), respectively, with 2 weeks period in between as recommended by (1) kg/h^{-1} nano-B and (500) g (1/2 kg) nano-Mo ha^{-1} is compatible with the stages of crop growth, and periods of one week between application and another, Table (2). Irrigation was done by a (GR) type drip irrigation system made for this purpose. The experiment was divided into two parts and a water meter was erected at the beginning to control the quantities of water to be applied according to the water rating of the potato crop [22]. Irrigation intervals from one irrigation to another do not reach more (50)% of the available water in the soil. Nitrogen fertilizers of both resources were applied using a drip irrigation system.

Leaf chlorophyll content (SPAD): Chlorophyll was measured in leaves 10 days after the fourth application. Fully expanded leaves, which are at the peak of their physiological activity for 10 plants and four leaves per plant, were selected by the (Spade-502) chlorophyll meter from Minolta Co. LTD (Nano-Mall.cm^{-2}) [23].

Dry vegetative yield (meg ha^{-1}): Ten plants were chosen from the center of each experimental unite and cut from the area adjacent to the soil and air-dried and then dried by an oven for 24 hours at (65)$^{\circ}$C. The dry weight was measured by a sensitive scale and was calculated based on the number of plants in the experimental unit to the number of plants per hectare.

Soft tuber yield (meg ha^{-1}) = total soft tuber yield of experimental unit × number of experimental units per hectare.

Bioogical yield (Meg ha^{-1}) = dry matter of the dry vegetative yield (Meg ha^{-1}) + dry tubers yield of treatment (Meg ha^{-1}).

% Starch in tubers = 17.55 + 0.89 (% dry matter in tubers - 24.18) [24].

Starch yield for treatment = % Starch in tubers × dry tubers yeild for treatment

Protein yield (Kg ha^{-1}): Protein yield was calculated on the basis of dry weight [24]

and according to the following formula:

Protein yield = Percentage of protein in tubers × dry tubers yield of treatment

Percentage of Protein-based on dry weight = percentage of nitrogen in tubers × 6.25

Ascorbic yield (Kg ha^{-1}): Ascorbic acid yield is calculated on the basis of soft weight [24] and according to the following equation:

Ascorbic yield =% Ascorbic acid × Soft tubers yield for treatment

Data were analyzed statistically according to the analysis of variance and the significant differences between the coefficients in the (RCBD) design at the 0.05 level of Duncan test [25] and the Genstat 2012 computing program.

Table (1): Chemical and physical proprieties of the field soil.

Property	Value	Estimated Methods
Particle size distribution (gm kg^{-1}soil)		
Clay **Silt** **Sand**	120 580 300	Kilmer and Alexander,1949
Texture	Silt clay loam	
CEC C mol^{+} kg^{-1}Soil	26.3	Salim and Ali,2017
OM gm kg^{-1}Soil	16.0	
Calcite gm kg^{-1}Soil	217	
pH	7.6	
EC(1:1) (dS m^{-1})	2.1	
Available macronutrients (mg kg^{-1}soil) **N** **P** **K**	27 14 290	Salim and Ali,2017 Landon,1984
Mo	0,6	Salim and Ali,2017
B	0.8	
Bulk density Mg m^{-3}	1.4	Landon,1984

Table (2): The experiment treatments and their quantities of fertilizer applications

Tr. No	Fertilizers percentages Treatments	10% of the total fertilizer amount per ha		20% of the total fertilizer amount per ha		30% of the total fertilizer amount per ha		40% of the total fertilizer amount per ha	
		kg or L ha^{-1}	g $100L^{-1}$	Fert*	Fo**	Fert	Fo	Fert	Fo
T_1	Control spray water only	0	0	0	0	0	0	0	0
T_2	Foliar application of nano Mo 5 %	0	12.5	0	25	0	37.5	0	50
T_3	Foliar application of nano B 9 %	0	25	0	50	0	75	0	100
T_4	Foliar application of nano (Mo+B)	0	12.5+25	0	25+50	0	75+37.5	0	100+50
T_5	Fertigation of Urea + Foliar application of water	30	0	60	0	90	0	120	0
T_6	Fertigation of Urea + Foliar application of nano Mo	30	12.5	60	25	90	37.5	120	50
T_7	Fertigation of Urea + Foliar application of nano B	30	25	60	50	90	75	120	100
T_8	Fertigation of Urea + Foliar application of nano (Mo+ B)	30	12.5+25	60	25+50	90	75+37.5	120	100+50
T_9	Fertigation of nano N + Foliar application of water	4	0	8	0	12	0	16	0
T_{10}	Fertigation of nano N + Foliar application of nano Mo	4	12.5	8	25	12	37.5	16	50
T_{11}	Fertigation of nano N + Foliar application of nano B	4	25	8	50	12	75	16	100
T_{12}	Fertigation of nano N + Foliar application of nano (Mo+B)	4	12.5+25	8	25+50	12	75+37.5	16	100+50

*Fertigation **Foliar application

III. Results and Discussion

Chlorophyll SPAD:

The results in Table (3) present the fertigation of urea and nano-nitrogen, foliar application of nano-fertilizers of molybdenum and boron in their various mono and binary combinations resulted in a significant increase in chlorophyll content SPAD. Tricombination of nano(N+B+Mo) the highest content of (56.7) SPAD compared to tricombination of (U+B+Mo) (38.4 and 50.6) SPAD, respectively. For dual treatments(N+B), resulted in the highest chlorophyll content (54) SPAD compared to the treatments of (N+Mo, U+B, U+Mo, and B+Mo), whish valued (53, 49.3, 48.1 and43.7) SPAD with significant differences among them compared to the control. Single application treatments nano-nitrogen resulted in (52.1) SPAD significant increase compared to the treatments of (U, B and Mo), which were (46.7, 40.3 and 39.6) SPAD, respectively, and a significant difference between them compared to the control treatment.

Dry vegetative yield (Meg ha^{-1}):

Table (3) The tricombination (N+Mo+ B) resulted in a significant increase in the dry vegetative yield, which reached (1.799) Meg ha^{-1} compared to the control treatment (0.890) Meg ha^{-1}. Thus, this treatment resulted in a significant increase compared to the treatment of tricombination resulting from (U+B+Mo), which made the dry vegetative yield value of (1.655) Meg ha^{-1}. Treatment of Nano (N+B) resulting significantly increased the dry vegetative yield as compared to the other di-treatments (U + B, N + Mo, and U + Mo), which had the highest dry vegetative yield (1.690) Meg ha^{-1}, while the rest of the treatments valued at (1.368, 1400 1.370) Meg ha^{-1}, respectively, with no significant differences among them.

Soft tuber yield (Meg ha^{-1}):

Results in Table (3) present that the highest soft tuber yield was achieved with the treatment of (N+Mo+B) (37.53) Meg ha^{-1} with significant increase over all of the treatments, including the tricombination of (U+Mo+B) of (33.12) Meg ha^{-1}. The treatment of nano (N+B) made significant increased the soft tuber yield (35.77) Meg ha^{-1} on the other bilateral treatments (U+B), (U+Mo), and (Mo+B), which resulted in (32.27, 30.91 and 25.03) Meg ha^{-1}, respectively. The single treatment of Nano-N, U, Nano B, and Nano Mo, which valued at (33.02, 30.43, 23.52 and 22.96) Meg ha^{-1}, respectively, all made significant increase compared to the control treatment (21.58) Meg ha^{-1}.

Biological yield (Meg ha^{-1}):

The individual foliar application treatments of nano molybdenum and nano boron and dual (Mo+B) did not lead to a significant increase in the biological yield. The highest means were achieved with Nano (N+B+Mo), Nano (N+B), (U+Mo+B), (U+B) and (U+Mo) (8.138, 7.976, 8.664, 8.171and7.701) Meg ha^{-1}, respectively, which showed no significant differences among them (table 3).

Stach yield (Kg ha^{-1}):

Individual urea fertigation treatment achieved the high significantly of starch yield (4.923) Meg ha-1 compare to control , spray of single B,Mo and dual (B+Mo) (2.323, 2.595, 2.651and 2.779) Meg ha^{-1} respectively which did not show a significant difference between them (table 3).

Protein yield (Kg ha^{-1}):

Tricombination (U+B+Mo) and treatment dual (U+B) of (682.6 and 655.9) kg ha^{-1} respectively, made significant increase in the protein yield compared to other treatments. These included the control (366.1) kg ha^{-1} except for the treatment of single U and the binary of (U+Mo) that resulted in (601.0 and 612.1) kg ha^{-1}, sequentially. The single and dual spray treatments of nano-B and Mo showed no significant difference compared to the control (table 3).

Ascorbic acid (kg ha^{-1}):

It is clear that all treatments of nano-fertilizers and their various combinations and urea fertigation resulted in a significant increase in the yield of ascorbic acid. The same trend of ascorbic acid content in tubers was achieved. The tri-nano-treatments (N+Mo+B) resulted in the highest ascorbic yield (653.8) kg ha^{-1} compared to the control treatment that gave (215.5) kg ha^{-1} and the tricombination of (U+B+Mo) (434.2) kgha^{-1}. Binary combinations (N+B), (N+Mo), (U+B), (U+Mo), and Mo+B) valued at

(609.3, 569.4, 476.9, 434.2 and 320.2) kg ha^{-1}, respectively. Ascorbic yield were significantly increased with these treatments compared to single treatments of foliar application. Single and dual spraying treatments were significantly higher than the control, as shown in table (3).

Table(3): Effect Fertigation of Urea and nano-N and foliar application of nano Mo and B fertilizers on growth and yield of potato

Tr. No	Chloro phyll SPAD	Dry vegetative yield Meg ha^{-1}	Fresh tubers Yield Meg ha^{-1}	Biological Yield Meg h^{-1}	Starch yield Meg ha^{-1}	Protein Yield Kg ha^{-1}	Ascorbic Yield Kg ha^{-1}
T_1	38.4 i	0.890 g	21.583 i	4.463 c	2.323 d	366.1 c	215.5 j
T_2	39.6 hi	1.022 fg	22.967 h	4.962 c	2.595 d	373.1 c	252.7 i
T_3	40.3 h	1.099 efg	23.517 h	5.126 c	2.651 d	381.0 c	283.8 h
T_4	43.7 g	1.144 cef	25.032 g	5.384 c	2.779 d	406.6 c	320.2 g
T_5	46.7 f	1.322 bcde	30.437 f	7.257 b	4.075 bc	601.0 ab	415.3 f
T_6	48.1 e	1.370 bc	30.912 f	7.701 ab	4.407 abc	612.1 ab	434.2 f
T_7	49.3 de	1.400 b	32.278 e	8.171 ab	4.745 ab	655.9 a	476.9 e
T_8	50.6 d	1.655 a	33.029 de	8.664 a	4.923 a	682.6 a	515.2 d
T_9	52.1 c	1.630 a	34.016 cd	7.344 b	3.774 c	464.0 bc	530.5 d
T_{10}	53 bc	1.368 bcd	34.534 c	7.367 b	3.967 c	475.7 bc	569.4 c
T_{11}	54 b	1.690 a	35.770 b	7.976 ab	4.175 bc	479.6 bc	609.3 b
T_{12}	56.7 a	1.799 a	37.525 a	8.138 ab	4.152 bc	481.3 bc	653.8 a

IV. DISCUSSION

The increase in the chlorophyll content in the leaves of plant was because of the role of nitrogen, which is necessary to the formation of RNAs, DNA and energy compounds such as ATP as well as the enzyme companions. Nitrogen enters the formation of enzymes and some vitamins, as well. It also has an important role in various physiological processes and gives the green parts of the plant the dark green color and the reason for the presence of this color in the plant to the chlorophyll, which is mainly in the process of carbon representation and this material is responsible for the process of photosynthesis in the leaves of the plant [26].

Nano-fertilizers increase the availability of ready-made nutrients to the plant, longer and by suitable release in line with plant growth that increases the formation of chlorophyll, the rate of photosynthesis, dry matter production, consequently, the overall plant growth. These results are similar to those obtained by [27] when potato crop was foliar fertilizers with nano-SMP (NPK + TE) and seaweed extract under drip irrigation. These results are also consistent with the results obtained by [28] when studying the effect of Nano-nitrogen fertigation on potato yield.

These increases can be attributed to the roles of chelated nano-fertilizer applied by spray solutions in many physiological processes such as increasing the chlorophyll content in the leaves, which is necessary to increase the efficiency of photosynthesis and the formation of the amino acid (Tryptophan) that is necessary for cell elongation. These interpretations are consistent with the study of [29]. The presence of these elements side by side works to reduce stomatal resistance and increase stomatal conductivity, which provides the plant with enough carbon dioxide and water to continue photosynthesis and withdraw nutrients from the soil, which leads to an increase in the growth and weight of the vegetative growth. The significant increase in dry matter of vegetative under fertigation and foliar application may due to the good processing of nitrogen, molybdenum, and boron during the application. These nutrients have important roles during the initial processes in the plant. The nitrogen plays an important role in plant life. It works to increase vegetative growth as well as to strengthen the root system.

The effect of boron foliar application plays a role in increasing the biological processes and the synthesis of sugars in the plant. The superiority of nano-fertilizers than the conventional fertilizers is attributed to their high surface area and slow-release that helps in the speed of absorption of nutrients and speed of penetration, synthesis, and movement. This leads to an increase in growth rate and an increase in yield and its quality (protein and starch) by activating the photosynthesis process [30]. Protein content significantly influenced depending on climatic conditions during the vegetation period, genetic traits and agricultural conditions [31,32].

The significant increase resulted by the soft tubers yield when nitrogen fertigation and sprayed of nano (B+Mo) due to the availability of the nitrogen element in the soil solution and slow release to suit the growth of the plant so that the plant absorption for a longer period and not lost by leaching and volatilization. Eventually, the increased amounts of this element absorbed by the roots of plants, the use of nitrogen increases the process of growth and productivity as well as the quality of yield [33]. These results are consistent with the study by [34] who noted that foliar fertilization with nano-fertilizers of molybdenum and boron plays an important role in photosynthesis, resulting in increased leaf area and finally increased yield. It is also consistent with what [35-37] found when boron foliar application increased the yield of the potato plant. The small particles of nano-fertilizers and their high surface area make them able to penetrate rapidly into plant tissues. This stimulates the action of plant hormones within the plant that promote the growth of secondary roots, which is reflected in growth and production [38].

The behavior of nano-fertilizers once enters the plant they binding to carriers such as Aquaporin, Endocytosis, and Ion channels. This behavior will lead to the formation of new openings that penetrate and penetrate the cell wall or walls and then stimulate water absorption and encourage plant growth and production [39],these results are consistent with those obtained by [40]. The highest yield of potato tubers was achieved with an increase of 38% using nitrogen fertilizers. Micronutrients applied to the vegetative part results consistent with those obtained by [34] who indicated that fertilization by foliar application with nano-fertilizers has an important role in stimulating photosynthesis, resulting in increased leaf area. Thus, increasing photosynthesis processes and increasing the yield. [41] found when boron foliar-applied on pepper plant by (0.25) % yielded a significant increase in productivity. This result is consisted also with [42-44].

The significance of the biological yield may be attributed to the availability of nutrients that create a nutritional balance of the plant regularly during the early stages of growth. It works to improve metabolic activity and metabolism processes. This, in turn, increases the various metabolic activities that are responsible for the division and elongation processes in the plant cell and thus increases the majority of vegetative growth indicators [45,46]. The presence of these elements side by side works to reduce stomatal resistance and increase stomatal conductivity, which provides the plant with enough carbon dioxide and water to continue photosynthesis and withdraw nutrients from the soil leading to an increase in yield [29,47].

Starch yield is a characteristic quality of potato tubers in determining nutritional and industrial value. Potato tubers are usually characterized by high dry matter content and starch as their main constituent,] 48[. When nutrients are available continuously and along the period of growth, especially the major elements N as the low soil readiness leads to weaken vegetative growth and reduces the size of plants and thus reduces the efficiency of carbon representation, which affects the amount of materials manufactured and stored in the tubers [49,50].

Boron is a micronutrient that is necessary for the natural growth and development of the plant. The immune function is the synthesis of RNA and is therefore essential for other plant physiological functions such as carbohydrates and protein metabolism [51]. Boron increases the protein concentration in cowpea, which activates the meristematic areas which can be reduced by lowering the rate of protein synthesis due to boron deficiency[52,53]. El-Dissoky and Abdel-Kadar (2013) observed the effect of boron foliar application on some potato varieties under sedimentary soil conditions. The boron levels (0, 30, 60 and 90) mg/L^{-1} showed that foliar application of B significantly affected specific tubular parameters, including protein content [54] in their experience clarify that the recommended application of NPK and boric acid significantly increased protein in potato tubers by (0.1) %.

The plant needs molybdenum in a small amount of (12 to 32) g/h^{-1} for physiological function [55]. Its effect on plants is similar to other essential nutrients. Its critical and toxicity deficiency levels vary from (0.1 to 1) mg/kg^{-1} depending on the plant species and plant parts [56]. Molybdenum works in conjunction with nitrate-enhanced enzyme activity to obtain mRNA-approved protein synthesis, but the enzyme activity will be faster if molybdenum is present [57]. The lack of molybdenum reduces the total number of proteins in the plant [58].

It is clear from these results table (3) that there is a direct relationship occurs between the yield of soft tubers and ascorbic products. These results are consistent with those obtained by[54,59] revealed in their study that the recommended application of NPK and boric acid increased by (0.1) % significantly increased vitamin C (ascorbic acid). The application of molybdenum promoted the growth of vegetable crops and also improved traits such as ascorbic acid [60]. Chen et al (2007). Plants that suffer from molybdenum deficiency had poor growth and low ascorbic acid content [56].

V. Conclusions

The best values of potato growth traits resulted when using nano-fertilizers, whether applied by fertigation or by foliar application. Nano-fertilizers had a positive effect on improving the quality of potato yield compared to conventional nitrogen fertilizer (urea). Potato plants treated with these fertilizers resulted in more soft and dry vegetative yield, potato fresh tuber yield, a higher nutrient content better than the comparison treatment in the presence of good water management and using drip irrigation method.

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