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Comparison of different types of fertilizers on growth, yield and quality properties of watermelon (*Citrullus lanatus*) in the Southeast of Kazakhstan

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Abstract

Over the years, the use of organic materials in farming has reduced due to the increase in the use of chemical fertilizers which are rich in readily available plant nutrients. Intensive use of chemical fertilizers may have depressing effect on yield of watermelon. The field experiment were conducted at the Experimental Clinic of the Laboratory "Selection of vegetable and melon crops" and in the laboratory "Biosafety and Biocontrol of vegetable and melon crops" of Regional Branch "Kainar" of the LLP "Kazakh Research Institute of Fruit and Vegetable Growing" which is located in the foothill zone of the southeast of Kazakhstan, to study the effects of different types of organic fertilizers (cow manure, poultry manure and biohumus) and recommended chemical fertilizer (NPK) on the characteristics of watermelon (growth parameters, yield and quality) of southeast of Kazakhstan. There were significant differences among the treatments in relation to fruit yield of watermelon, growth paremeters and quality properties (dry matter, total sugar, Vitamin C and NO_3-N). Recommended fertilizer dose ($N_{90}P_{60}K_{60}$) had the highest fruit yield of watermelon and growth paremeters followed by manure applied at 40 t ha^{-1}. All the fertilizer treatments had higher yield of watermelon than control. From this study, the use of manure as an organic fertilizer in the cultivation of watermelon could be used as alternative to chemical fertilizer. It is recommended that manure at 40 t ha^{-1} be adopted for watermelon cultivation in in the Southeast of Kazakhstan.

Keywords: Watermelon, fertilizer, fertilization, manure, yield.

Introduction

Organic farming is an eco-friendly means of production based on sustainable productivity that doesn't use artificial components such as chemical fertilizers or pesticides. Organic food is food produced using methods that do not include modern artificial additives such as pesticides and chemical fertilizers, does not contain genetically modified organisms and is not treated with radiation, industrial solvents or chemical food additives. Unfortunately, in the World, currently, there is only about 1% of organic farming (Duram, 2005; Hansen, 2010). In Asia, the top three organic farming nations by land area are China, India, and Kazakhstan. Kazakhstan has about 291,203 ha of land used for organic farming. Organic farming in Kazakhstan is becoming increasingly popular due to the growing demand for organic products, availability of large tracts of agricultural land, and comparative advantage such as low labor costs. Organic farmers engage in both horticulture and cattle farming some of which are exported. Watermelon cultivation is one of the main agricultural sectors in Kazakhstan that is largely come into play to organic farming.

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Watermelon (Citrullus lanatus) is a member of the cucurbit family (Cucurbitaceae), which also includes cantaloupes, cucumbers, pumpkins, squash, zucchini and butternuts. It is one of the most widely cultivated crops in the world. Its global consumption is greater than that of any other cucurbit (Schaffer and Paris, 2016). Watermelons have the greatest world production of any cucurbit, exceeding 63 million tonnes according to the FAO. Not surprisingly, China is by far the largest producer of watermelons, with over 38 million tonnes. The principal watermelon producing countries in Asia are China, Turkey, Iran and Kazakhstan. China produces over 50% of the world supply. Kazakhstan produced 1.2 million tons of watermelon (12^{th} largest producer in the world) in 2018. Watermelon is a good cash crop in Kazakhstan with very good market opportunities, particularly in urban areas (FAO, 2020).

In organic farming, the soil becomes rich in nutrients; therefore, crops grow healthy and can be resistant to pests and diseases, making the quality of the products more nutritious, tastier and contain substances that are good for health. In order to improve the yield of watermelon, the nutrient contents should be increased to increase the soil fertility. One of the ways of improving soil fertility is by maintaining its organic matter. The organic matter content in soil can be increased by the addition of organic wastes (Gülser and Candemir, 2015) such as municipal solid waste, food waste, biowaste, manure, sewage sludge, etc. The quality of soil and improvement of soil health can be restored by incorporation of recycling organic wastes in the soil (Kızılkaya, 2005, 2008). Debiase et al. (2016) reported that urban areas produce a huge amount of degradable organic wastes such as Municipal solid waste and sewage sludge. These wastes contain several macro- and micro-nutrients that can be used as potential organic fertilizers for crop production. Goss et al. (2013) are of the same opinion. Several studies have been done related to organic amendments on improving soil physical, chemical, and biological properties, providing essential plant nutrients to stimulate plant growth and yield (Kızılkaya and Hepşen, 2004, 2007; Candemir and Gülser, 2010; Gülser et al., 2017; Kızılkaya et al., 2021). Rodriguez-Vila et al. (2016) found that organic amendments sustain soil properties by increasing organic matter, nutrient content, microbial activity and thus increase crop growth and yield. Organic wastes not only influence soil properties, but also play a great role in the growth and development of plants and thus improve agricultural productivity. Studies by Papafilippaki et al. (2015) and Mbarki et al. (2008) recorded positive responses of spiny chicory and Ryegrass to organic waste application. Debiase et al. (2016) reported that incorporated organic wastes gave 32% higher yields than an unfertilized field. Moreover, the authors con-firmed that SS application ensured 12% higher yield compared to municipal solid waste addition of a wheat field. These amendments not only increase crop yields, but also minimize the risk of nitrogen leaching from the soil. There is paucity of information on the use of organic wastes for the production of watermelon in southeast of Kazakhstan.

This study was carried out to evaluate the effects of different types of organic fertilizers (cow manure, poultry manure and biohumus) and recommended chemical fertilizer (NPK) on the characteristics of watermelon (growth parameters, yield and quality) of southeast of Kazakhstan.

Material and Methods

Description of the Study Sites

The experiments were conducted at the Experimental Clinic of the Laboratory “Selection of vegetable and melon crops” and in the laboratory “Biosafety and Biocontrol of vegetable and melon crops” of Regional Branch “Kainar” of the LLP “Kazakh Research Institute of Fruit and Vegetable Growing” which is located in the foothill zone of the southeast of Kazakhstan (43°09'32.8"N 76°26'57.3"E) North Slope of Zailiyskiy Alatau Mountains (Altitude : 1000-1050 m) during the growing season 2019-2020 with a view to finding out the Watermelon expo as well as determining the different organic fertilizers such as biohumus, manure, poultry manure, grain straw, biohumus and recommended chemical NPK fertilizers. The locations of the evaluations were characterized by the continental climate (large daily and annual fluctuations in air temperature, characterized by cold winters and long hot summers), the air temperature reaches minimum values in January (-32,-35^{0}C), and maximum values in July (37-43^{0}C). The warm period lasts 240-275 days, the frost-free period is 140-170 days and an annual amount of precipitation is 350-600 mm.

The soil belongs to the general soil type of dark chestnut. The land was medium high with loamy. Before conducting the experiment, the soil sample was analyzed from Kazakh Research Institute of Soil Science and Agricultural Chemistry named after U. Uspanov. The soil was characteristically slightly alkaline (pH 7.3-7.4), soil organic matter 2.9-3.0% (moderate), total N 0.18-0.20% (high), available P_2O_5 35-40 mg kg^{-1} (moderate), available K_2O 360-390 mg kg^{-1} (low), cation exchange capacity 20-21 me $100g^{-1}$ soil, bulk density 1.1-1.2 gr cm^3, field capacity 26.6%.

The sources of chemical fertilizers utilized were: ammonium nitrate 34.5% N, double superphosphate 46%P_2O_5 and potassium chloride 60% K_2O. The source of the organic fertilizer utilized was biohumus, manure, poultry manure, grain straw, biohumus, whose contents of organic matter, nitrogen, phosphorus and potassium are presented in Table 1.

Table 1. Composition of organic wastes, measured variables

Organic materials	Organic matter, %	C:N	N, %	P_2O_5, %	K_2O, %
Manure	21	24,4	0,50	0,25	0,60
Poultry manure	40	14,5	1,60	1,50	0,80
Grain Straw	35	40,6	0,50	0,25	0,80
Biohumus	40	10,5	2,20	1,80	1,60

Treatments and Experimental Design

The experiment was performed using a completely randomized block design with four replications. The soil was ploughed, harrowed, and flat seedbeds measuring 10 m x 3,5 m (35 m^2) were made. Each plot was separated from the other by a one-metre alley. Fertilizer was applied using grain drill. The design of the experiment was a randomized complete block replicated thrice. Treatments comprised control, biohumus, manure, poultry manure, grain straw, biohumus and recommended chemical NPK fertilizers. The experimental field was prepared in accordance with a standard practice used by RB Kainar of LLP Kazakh Research Institute of Fruit and Vegetable Growing. Other agronomic practices and data collection were conducted based on the recommendations ($N_{90}P_{60}K_{60}$) of Kazakh Research Institute of Fruit and Vegetable Growing. The experiment was performed with the following 8 treatments.

- T1: Control (non-fertilization)
- T2: Recommended fertilizer dose ($N_{90}P_{60}K_{60}$)
- T3: Biohumus (10 t ha^{-1})
- T4: Biohumus (15 t ha^{-1})
- T5: Manure (40 t ha^{-1})
- T6: Poultry manure (5 t ha^{-1})
- T7: Poultry manure (10 t ha^{-1})
- T8: Grain Straw (3 t ha^{-1}) + Recommended fertilizer dose ($N_{90}P_{60}K_{60}$)

The trial was implemented on May and the harvest began in the first decade of August and Trial was well protected against insects and weeds during the season. Watermelon expo was planted on 26 May 2019 and 22 May 2020. The size of each elemental plot was 35 m^2 and included seven planting rows 1.5 m apart with eight plants per row, with a distance of 1.5 m between plants. The irrigation system, which was similar to that used by farmers in the area, consisted of one drip line per crop row and emitters of 2 L/h, 0.5 m apart.

Watermelons were harvested by hand when the fruit matured. The watermelons were picked by experienced persons and in general fruit were considered mature when the tendril nearest to fruit start to dry, and color of fruit on the bottom side changed from creamy white to yellowish. Fruits were measured and weighed during harvest and total yield and phenological observations were determined. In addition, the total sugar content was determined using the Bertrand method, Vitamin C (Ascorbic acid) content was determined titrimetric method using 2,6-Dichlorophenol indophenol (DCPIP), nitrate content was determined potentiometrically with ion-selective electrodes (AOAC, 2005).

Results and Discussion

Yield and growth parameters

The effects of the organic and chemical fertilizer on the fruit yield are shown in Table 1. The fruit yield of watermelon ranged from 16.84 t ha^{-1} to 25.64 t ha^{-1}, with an average of 23.13 t ha^{-1} (Table 1). The average fruit yield in this study area was higher than the 41.7 t ha^{-1} in the whole China, and much higher than the world yield of 32.1 t ha^{-1} in 2018. The reason for these significant differences was the diversity of watermelon varieties, climate, and field management (Gusmini and Wehner, 2005). There were no significant differences among treatments for yield of watermelon between 2019 and 2020. Recommended fertilizer dose ($N_{90}P_{60}K_{60}$) with chemical fertilizers and organic wastes used at various rates increased the yield of watermelon. However, recommended fertilizer dose (T2) has shown a great influence on the yield of watermelon followed by Manure (T5). The lowest nutrients recorded by the control experiment might be the reason why the yield parameters were very low compared with other treatments. Biohumus (T3 and T4) and poultry manure (T6 and T7) were similar in their effect on yield of watermelon and the difference was significant ($P < 0.05$) as shown in Table 1. The results are in total agreement with those obtained by Massri and Labban (2014) who found that chemical fertilizers ($N_{20}P_{40}K_{25}$) had positive impact on watermelon productivity. In their study, chemical fertilizer gave around 11 t ha^{-1} which are very close to our result. Abul-Soud et al. (2010) also observed an increase in average fruit weight when levels of livestock manure and liquid pig manure were applied to the soil. However, melon plants growing in soils containing different sources and levels of organic matter including manure.

Table 1. Effect of different types of fertilizers on fruit yield of watermelon (Citrullus lanatus)

Treatments	Fruit Yield, t/ha			Increase in fruit yield	
	2019	2020	Average	t/ha	%
T1	17.00a	16.68a	16.84	-	-
T2	26.19d	25.08c	25.64	8.80	52.23
T3	23.51b	22.40b	22.96	6.12	36.31
T4	24.94c	23.83bc	24.39	7.55	44.80
T5	25.96cd	24.95c	25.46	8.62	51.16
T6	23.84bc	22.73bc	23.29	6.45	38.27
T7	24.44bc	23.33bc	23.89	7.05	41.83
T8	23.14b	22.03b	22.59	5.75	34.12
LSD $_{\alpha=0.05}$	1.18	1.71			

T1: Control (non-fertilization); -T2: Recommended fertilizer dose (N90P60K60); T3: Biohumus (10 t ha^{-1}); T4: Biohumus (15 t ha^{-1}); T5: Manure (40 t ha^{-1}); T6: Poultry manure (5 t ha^{-1}); T7: Poultry manure (10 t ha^{-1}); T8: Grain Straw (3 t ha^{-1}) + Recommended fertilizer dose ($N_{90}P_{60}K_{60}$)

In Table 2, different types of fertilizers did significantly influence growth parameters of watermelon (Citrullus lanatus) during the fruit formation in both years. Different types of fertilizers influenced higher value in 2020 than in 2019. The control (T1) consistently produced the smallest growth parameters of watermelon such as lenght of the main shoot, quantity of stems, base thickness, intermode lenght, leaf width, leaf lenght, quantity of inflorescences, quantity of fruits, fruit diameter and average weight of the 1st fruit in each year. Recommended fertilizer dose (T2) has shown a great influence on growth parameters of watermelon followed by Manure (T5).

Table 2. Effect of different types of fertilizers on growth parameters of watermelon (Citrullus lanatus) during the fruit formatiion

Treatments	Years	Length of the main shoot, cm	Quantity of stems, pcs.	Base thickness cm	Internode length, cm	Leafstick length, cm	Leaf width, cm	Leaf length, cm	Quantity of inflorescences, pcs.	Quantity of fruits, pcs.	Fruit diameter, cm	Average weight of the 1st fruit, g
T1	2019	2.07	4.75	1.39	5.55	5.55	5.55	5.55	19.35	1.89	13.89	598.95
	2020	2.19	4.85	1.44	5.97	6.16	7.57	9.69	19.45	1.95	14.86	599.35
	Average	2.13	4.80	1.42	5.76	5.86	6.60	7.62	19.40	1.92	14.38	599.15
T2	2019	2.05	5.25	1.60	7.35	7.35	7.35	7.35	24.95	2.25	17.90	1146.9
	2020	2.72	5.30	1.79	7.49	7.82	9.22	12.17	25.05	2.35	18.70	1147.1
	Average	2.39	5.28	1.70	7.42	7.59	8.30	9.76	25.00	2.30	18.30	1147.0
T3	2019	2.45	5.05	1.45	6.55	6.55	6.55	6.55	20.50	2.05	16.90	865.90
	2020	2.55	5.00	1.53	6.64	6.38	8.02	10.66	21.55	2.10	17.06	866.20
	Average	2.50	5.03	1.49	6.60	6.47	7.30	8.61	21.03	2.08	16.98	866.05
T4	2019	2.55	5.05	1.45	6.70	6.70	6.70	6.70	24.08	2.15	18.75	1117.70
	2020	2.64	5.15	1.62	6.81	7.16	8.40	11.1	24.20	2.35	18.90	1118.10
	Average	2.60	5.10	1.54	6.76	6.93	7.60	8.91	24.14	2.25	18.83	1117.90
T5	2019	2.70	5.05	1.55	7.00	7.00	7.00	7.00	24.75	2.25	18.18	1046.65
	2020	2.80	5.20	1.67	7.22	7.28	8.68	11.2	24.85	2.35	18.28	1047.70
	Average	2.75	5.13	1.61	7.11	7.14	7.80	9.10	24.80	2.30	18.23	1047.18
T6	2019	2.39	4.75	1.39	5.85	5.85	5.85	5.85	21.35	1.90	17.00	833.70
	2020	2.49	4.90	1.49	6.56	6.29	7.90	10.46	21.45	2.00	17.10	834.10
	Average	2.44	4.83	1.44	6.21	6.07	6.90	8.16	21.40	1.95	17.05	833.90
T7	2019	2.49	5.00	1.45	6.05	6.05	6.05	6.05	21.65	2.05	18.10	918.80
	2020	2.59	5.15	1.55	6.73	6.84	7.99	10.84	21.75	2.25	18.24	919.70
	Average	2.54	5.08	1.50	6.39	6.45	7.00	8.45	21.70	2.15	18.17	919.25
T8	2019	2.47	4.95	1.40	6.85	6.85	6.85	6.85	20.75	2.08	18.05	919.85
	2020	2.57	5.10	1.54	6.91	6.95	7.99	10.46	20.85	2.15	18.20	920.95
	Average	2.52	5.03	1.47	6.88	6.90	7.40	8.66	20.80	2.12	18.13	920.40

T1: Control (non-fertilization); -T2: Recommended fertilizer dose (N90P60K60); T3: Biohumus (10 t ha^{-1}); T4: Biohumus (15 t ha^{-1}); T5: Manure (40 t ha^{-1}); T6: Poultry manure (5 t ha^{-1}); T7: Poultry manure (10 t ha^{-1}); T8: Grain Straw (3 t ha^{-1}) + Recommended fertilizer dose ($N_{90}P_{60}K_{60}$)

Quality properties

The quality indicators of watermelon fruits such as dry matter, total sugar, Vitamin C and NO_3-N as affected by treatments are shown in Table 3. Vitamin C is an important water-soluble vitamin that had being implicated in many life processes apart from its antioxidant property (Chambial et al., 2010). Recommended fertilizer dose (T2) had generally highest dry matter, total sugar, Vitamin C and NO_3-N compared with the other treatments. Poultry manure (T7) and Manure (T5) came second and it was significantly better than the other treatments. The highest NO_3-N obtained from recommended fertilizer dose (T2) treatment may probably due to faster release of nutrient contents of NPK than those of other treatment. Similar reports have been made on faster nutrient release from inorganic fertilizers compared to organic nutrients sources when used for the production of vegetables, cereal and tree crops (Adeoye et al., 2008; Ainika et al., 2012). The lowest nutrients recorded by the control experiment might be the reason why the yield parameters were very low compared with other treatments. In this research results showed that the content of NO_3-N in watermelon products was much lower than the maximum permissible concentration (60 mg kg^{-1} for watermelon) on variants where organic fertilizers were applied to the watermelon 39-62 mg kg^{-1}. In experiments where Recommended NPK fertilizers were used, the excess of NO_3-N is more than 3 times the maximum permissible concentration. Thus, these fruits could be dangerous for consumption. Tamme et al. (2006) recommended that the average nitrate content in watermelon was 95 mg kg^{-1}. The results of our investigations showed that (Table 3) the content of nitrates in other treatments (organic fertilizers) was less than the maximum level for nitrates as recommended by the Tamme et al (2006), 95 mg kg^{-1}. This means that the watermelons are safe for consumption.

Table 3. Effect of different types of fertilizers on quality properties of watermelon (Citrullus lanatus)

Treatments	Dry matter, %			Total sugar, %			Vitamin C, mg in 100g			NO_3-N, mg / kg		
	2019	2020	Average	2019	2020	Average	2019	2020	Average	2019	2020	Average
T1	8.3	9.2	8.8	12.82	13.62	13.22	5.48	6.48	5.98	15	10	12.5
T2	12.6	13.1	12.9	16.98	17.98	17.48	8.54	8.64	8.59	180	196	188.0
T3	10.5	11.9	11.2	15.88	16.98	16.43	7.10	7.20	7.15	40	38	39.0
T4	11.4	12.4	11.9	17.29	18.20	17.75	7.84	7.95	7.90	62	55	58.5
T5	12.4	13.3	12.9	16.82	17.52	17.17	8.53	8.64	8.59	65	59	62.0
T6	11.0	12.0	11.5	15.70	16.60	16.15	7.85	7.92	7.89	56	51	53.5
T7	12.9	13.1	13.0	16.62	17.52	17.07	8.54	8.64	8.59	63	57	60.0
T8	12.0	13.0	12.5	16.30	17.10	16.70	7.88	7.92	7.90	63	57	60.0

T1: Control (non-fertilization); -T2: Recommended fertilizer dose (N90P60K60); T3: Biohumus (10 t ha^{-1}); T4: Biohumus (15 t ha^{-1}); T5: Manure (40 t ha^{-1}); T6: Poultry manure (5 t ha^{-1}); T7: Poultry manure (10 t ha^{-1}); T8: Grain Straw (3 t ha^{-1}) + Recommended fertilizer dose ($N_{90}P_{60}K_{60}$)

Conclusion

This study showed that manure at 40 t ha^{-1} gave the best performance among all other organic fertilizers used due to its impact on the growth and yield of watermelon and its quality properties. Given its superior responses, manure applied at a rate of 40 t ha^{-1} could serve as alternative to recommended chemical fertilizer. It is therefore reasonable to recommend the use of organic fertilizer 40 t ha^{-1} cultivation of watermelon in the Southeast of Kazakhstan.

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