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EFFECT OF NANO, CONVENTIONAL NPK, ORGANIC FERTILIZERS AND PLANTING METHODS ON GROWTH AND YIELD CHARACTERISTICS OF MELON PLANTS (CUCUMIS MELO L.) UNDER GREENHOUSE CONDITIONS

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Abstract

This study aimed to determine the effect of different fertilizer materials, namely NPK-based nanofertilizers, conventional chemical fertilizers, and organic fertilizers, as well as planting methods on the productivity and quality of melons cultivated under greenhouse conditions. A randomized complete block design was used involving five treatments: control (no fertilizer added), NPK fertilizer (20:20:20) at 300 kg ha^{-1}, nano fertilizer (10:12:12) at 150 ml in 200 L ha^{-1}, NPK foliar fertilizer (20:20:20) 20 g L^{-1}, and organic fertilizer at 20 L in 300 L ha^{-1} through fertigation, as well as two planting methods (transplanting and direct seeding). These treatments and the control were replicated 4 times, and after the crops were established various growth and yield parameters were measured, such as plant height, leaf chlorophyll content, fruit weight, fruit diameter, and sugar content. The data was analyzed using analysis of variance (ANOVA) and SPSS version 26 at the 5% significance level was used. The results indicated that overall fertilizers application and planting methods significantly ($p < 0.05$) increased the studied parameters. The tallest plants (172.6 cm) were from plots planted by direct seeding and the application of NPK (20:20:20) fertilizer. Similarly, plants with direct seeding treated with either NPK fertilizer (20:20:20) or nano-fertilizer (10:12:12) recorded higher fruit weights (35.6 kg $plot^{-1}$), larger fruit diameters (44.5 cm), and fruit sugar content (8.8%), compared to the control which registered the lowest values at 6.7 kg $plot^{-1}$, 42.2 cm, and 7.2%, respectively. The results suggest that direct seeding together with balanced NPK fertilizer (20:20:20) and nano-fertilizer applications can be recommended for growing melons in the greenhouse.

Keywords: Nanofertilizer, Melon Plant, Planting Method, Organic Fertilizer, Greenhouse.

تأثير سماد NPK النانوي والتقليدي وسماد العضوي والرشى وطريقة الزراعة في بعض صفات نمو وحاصل البطيخ المزروع في البيوت المحمية

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الخلاصة

أجريت هذه الدراسة لتقييم تأثير استراتيجيات التسميد المختلفة باستخدام – سماد النانوي– NPK، السماد التجاري (المعدني) والسماد العضوي، اضافة الى طريقة الزراعة (الزراعة عن طريق الشتلات والبذار مباشرة) في انتاجية وجودة البطيخ المزروع في الدفيئة (الزراعة المحمية). صممت التجربة عي تصميم القطاعات العشوائية الكاملة في البيت المحمي، وتضمنت التجربة دراسة تأثير خمسة معاملات وهي معاملة السيطرة (بدون إضافة أي سماد)، معاملة التسميد بسماد المعدني NPK (20:20:20) بمعدل 300 كجم هكتار$^{-1}$، معاملة سماد النانو– NPK (10:12:12) بمعدل 150 مل في 200 لتر هكتار$^{-1}$، معاملة التسميد الورقي بسماد– NPK (20:20:20) بمعدل 20 جم لتر$^{-1}$ ومعاملة اضافة السماد العضوي (سماد عضوي مصنع يسمى بيوران يحتوي على N، P، K، Mn، Fe، Zn وOC بنسبة 3.49%، 1.17%، 2.16%، 0.006%، 0.007%، 0.003%، و8.56% على التوالي) بمعدل 20 لتر في 300 لتر هكتار$^{-1}$، والتي اضيف عن طريق التسميد بالري. بالإضافة إلى استخدام طريقتين للزراعة والزراعة عن طريق الشتلات والبذار المباشر. تم قياس معايير النمو التالية: ارتفاع النبات، محتوى الكلوروفيل في الاوراق، وزن الثمرة وقطرها ومحتوى السكر في الثمرة. أشارت النتائج إلى ان جميع الاسمدة المستخدمة وطرق الزراعة ادت الى زيادة معنوية ($p < 0.01$) في الصفات المدروسة للبطيخ. اذ سجلت اعلى طول للنبات (172.6 سم) في معاملة المزروعة بالبذار المباشر ومعاملة إضافة سماد– NPK (20:20:20). كما سجلت نباتات المزروعة عن طريق البذار المباشر وكذلك المعاملة بسماد NPK (20:20:20) والمعاملة بسماد النانو– NPK (10:12:12) أعلى وزن للثمرة (اذ بلغت الى 35.6 كجم للمعاملة$^{-1}$)، أكبر قطر للثمرة (اذ باغت الى 44.5 سم) واعلى محتوى للسكر في الثمرة (8.8٪) مقارنة بمعاملة السيطرة التي سجلت اقل القيم للصفات اعلاه (6.7 كجم للمعاملة$^{-1}$، 42.2 سم و7.2٪) على التوالي. تشير النتائج إلى أنه يمكن التوصية بالبذار المباشر والتسميد بسماد NPK المتوازن (20:20:20) واستخدام الأسمدة النانوية في زراعة البطيخ في البيوت المحمية.

كلمات مفتاحية: سماد النانو– NPK، نبات البطيخ، طريقة الزراعة، سماد عضوي، البيت المحمي.

Introduction

Melon (*Cucumis melo* L.) belongs to the Cucurbitaceae family and originated in both Iran and Pakistan (12). The crop is known to be useful for its medicinal value, and is thus widely distributed around the globe (23). The fruit is remarkably delicious whilst simultaneously containing various medicinal properties. It is also rich in bioactives such as essential fatty acids, polyphenols, and carotenoids that provide many health advantages (12). The approximate annual consumption of melons in the Kurdistan region of Iraq (KRI) is about 62,847 Mg, 61% (38,367 Mg) of which is produced locally (19) Annual global production of the fruit is more than 28.5 million metric tons (10). There is a clear need to increase melon production in the KRI to ensure permanent access to the market.

Greenhouse farming was developed in modern agricultural practice as it allows most of the growth factors to be controlled and provides a suitable environment for the production of high quality crops throughout the year (30). Greenhouse melon farming using best management practices and fertilization is vital in influencing a plant's growth, development, and yield (34). Fertilizers have an important role in the growing of greenhouse crops, with NPK and its rapid release of nutrients into the soil specifically offering the best potential for sustaining soil fertility and crop productivity (33). Due to their specialized roles, these nutrients need to be applied at appropriate times and amounts (31). However, regular use of chemical fertilizers results in soil deterioration and a variety of adverse environmental impacts such as nutrient leaching and water contamination (17). Organic fertilizers derived from plant and animal sources serve as soil improvers, enhancing physical structure, stimulating microbial activity, and gradually increasing organic matter content, thereby benefiting overall soil properties (5 and 18). Previously, the main focus was on synthetic fertilizers, but concerns about the environment and food safety have directed researchers to explore alternative methods such as the use of organic matter together with nano-based fertilizer technology (4).

Nano-fertilizers (nano fertilizers comprise tiny particles measured in nanometers, or one billionth of a meter), can improve nutrient usage efficiency and reduce nutritional deficiencies in crops. Conventional fertilizers can lose up to 50-70% of their N to the environment through leaching, volatilization, or runoff, leading to water and air pollution (11). The P-fertilizers are susceptible to fixation in soil, making them unreadable to plants and requiring repeated applications. These losses limit fertilizer effectiveness and contribute to environmental degradation, affecting the quality of water and soil. Plants can readily absorb nano-sized materials as these substances offer enlarged surface areas for better interactions with plant roots. Research provides evidence that nano-fertilizers can greatly improve nutrient use efficiency while also reducing the environmental impact and promoting cleaner yields (15). They have the potential to boost nutrient use efficiency by up to 30% and crop yields by 20% compared to traditional fertilizers, allowing them to replace up to 50% of conventional fertilizers and reduce their environmental impact (27). Nanofertilizers show the potential to operate synergistically with the usual organic and inorganic fertilizers in greenhouse farms by delivering specific nutrients more efficiently, leading to better plant growth while diminishing by-products (28). They are known to deliver nutrients slowly and gradually for more than 30 days, which helps improve nutrient use efficiency while causing no negative side effects (32). According to research, nanofertilizers are more efficient in providing nutrients to plant roots in terms of the intensive cropping system and improving the yield and quality. As a result, they are appropriate for cropping systems requiring a high level of nutrient control, such as melons grown in greenhouses (7).

Furthermore, planting methods whether using transplantation or direct seeding produces different effects on melon growth and yield in greenhouse. As such, their success depends on the evaluation of each strategy since they demonstrate distinct advantages and drawbacks (6). Currently, no scientific research in Iraq, including the KRI, has investigated these aspects/approaches in designing and implementing greenhouse production methods. This had led to issues of resource efficiency, environmental sustainability, and economic viability for cultivation under controlledcondition systems that are best optimized for modern agriculture. Therefore, the objective of this study is to compare two planting methods (transplanting and direct seeding) and different fertilization strategies using NPK- based, nano-fertilizers, conventional NPK fertilizers, and organic fertilizer on the productivity and is quality of melons cultivated in greenhouses.

Materials and Methods

The study was conducted during the 2024 cropping season at a field of the Directorate of Agriculture and Training Center, Erbil-Iraq in the semi-arid region of KRI located at 36° 8′ 29″ N, Long 44° 1’ 5” E. and 390 m elevation. Prior to planting about 1 kg of composite soils were collected from the field at 30 cm depth following the zigzag method of sampling, using a stainless steel scoop. The samples were immediately air-dried, homogenized, and grounded to pass through a 2 mm sieve. They were sent to the Soil Laboratory of the Erbil Research Center at the Ministry of Agriculture and Water Resources of KRI, for analysis of selected physicochemical properties. The results are presented in Table 1.

Table 1: Selected physicochemical properties of the soil.

Parameter (%)	Value	Parameter	Value
Clay	19.00	EC (mS m^{-1}) $_{(1:2.5)}$	40.00
Silt	37.70	Total N (g kg^{-1})	0.11
Sand	43.30	Olsen P (mg kg^{-1}) $_{\text{Olsen method}}$	17.00
Texture (USDA)	loam	K (mg kg^{-1})	146.00
pH $_{(1:2.5)}$	7.97	OM (%)	1.03

Before planting, the land was prepared manually after plowing, bringing the soil to a leveled bed in separate plots. The land was divided into 2 equal parts based on planting type (direct-seeding and transplanting). Each part had 4 equal lines of 1 m wide and 22 m length and each line was divided into 5 equal plots of 4 m^2. A total of 14 melon plants (Alpes F1) were planted in each plot. The melon seeds were manually sown on March 17, 2024 at a depth of 1.5–2 cm in 1m-apart rows and inter-row spacing of 40 cm. In addition, melon seeds were also sown in plastic trays filled with a peat moss medium to produce seedlings. The greenhouse was divided into two sections with the sunrise and sunset sides designated for direct seeding and for transplanting seedlings, respectively. The drip irrigation system was utilized for watering the plants.

The experiment comprised 5 treatments: control, NPK (20:20:20), nanofertilizer (Nano Energy Liquid Fertilizer by Agri Sciences,1–100 nm), NPK foliar and organic fertilizer, and 2 types of planting i.e., direct-seeding and seedlings. NPK fertilizer (20:20:20) was added at the rate of 300 kg ha^{-1}, nanofertilizer (10:12:12) at 150 ml in 200L ha^{-1}, NPK foliar fertilizer (20:20:20) at20 g L^{-1}, and organic fertilizer (brand name Bioran containing N, P, K, Mn, Fe, Zn, and OC at rates of 3.49%, 1.17%, 2.16%, 0.006%, 0.007%, 0.003%, and 8.56%, respectively) at 20 L in 300 L ha^{-1} through fertigation in 4 doses 22, 37, 73 and 93 days after sowing. All fertilizers used were based on the manufacturer's instructions. The experiment was set up in a randomized complete block design (RCBD) with 4 replications.

Growth, yield, and quality analyses data such as plant height (cm) and leaf chlorophyll index (SPAD) were taken after 43 days from germination and when the plants started to fruit. The fruit-weight per plant, fruit size, and sugar content were taken from the first pick on June 15, 2024, and occasionally until the end of the experiment and the last pick on August 29, 2024. The data were subjected to statistical analysis of variance (ANOVA) using SPSS version 26 at the 5% significance level, while the Duncan test was used for comparison of means.

Results and Discussion

Plant height (cm) and leaf chlorophyll index (SPAD) were taken after 43 days from germination and when the plants started to set fruit (Figures 1 and 2). The results showed that application of different types of fertilizers in general significantly affected ($P < 0.05$) melon plant height with NPK fertilizer (20:20:20) producing the highest value (113.5 cm). Despite the increase in leaf chlorophyll index (SPAD) from all types of fertilizer applications, the NPK fertilizer (20:20:20) significantly increased ($P < 0.05$) this parameter. The highest leaf chlorophyll content 31.9 was recorded in samples treated with NPK fertilizer (20:20:20) while the lowest 29.9 was obtained in the control samples. The results showed significant differences between different fertilizers materials on growth and yield of the melon under greenhouse conditions.

The addition of NPK fertilizer (20:20:20) significantly increased both chlorophyll content (SPAD) and plant height (Figures 1 and 2), especially in the direct seeding method (Table 2). These parameters are considered the main indictors for photosynthetic efficiency and overall plant health and growth directly affect by fertilization (24 and 34). This increase in plant height and chlorophyll content might be linked to balanced supply of nutrients by the NPK fertilizer (20:20:20). The good response of muskmelon to NPK fertilizer, as evidenced by the significant increase in vegetative growth and fruit production, is consistent with previous researches on cucurbits, including cucumber muskmelon (2), pepino melon (20), egusi melon (23), watermelon (14), pumpkin (21), and cucumber (8). This balanced nutrient mixture (NPK) is likely to have played an important role in fostering optimal plant growth and development mainly due to the important effect of N, P, and K on the general properties and functions of crops. They promote root and inter-root microbial exudation as well as enhance the effectiveness of fast-acting soil nutrients that can be directly absorbed and utilized by the plant, which ultimately affects yield (16).

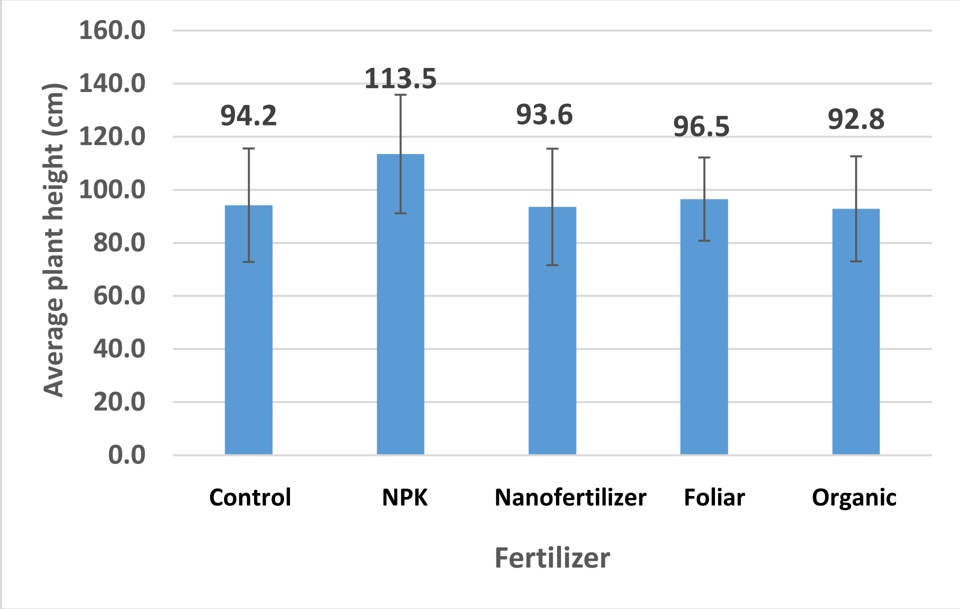

Fig. 1: Average melon plant height.

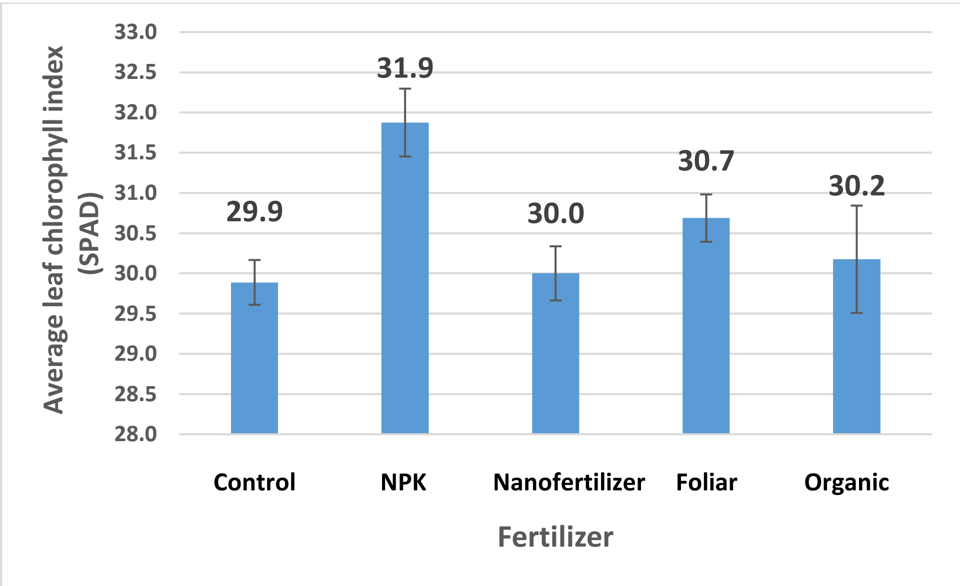

Fig. 2: Average leaf chlorophyll index (SPAD).

Table 2 shows the interaction effect of fertilizers and planting methods on the plant height and leaf chlorophyll content of melon. The addition of all types of fertilizer except organic fertilizer on direct seeding significantly raised ($P < 0.05$) plant heights, with the highest (172.6 cm) and the lowest (37.7 cm) recorded for NPK (20:20:20) fertilizer and the control, respectively. However, there was no significant effect on leaf chlorophyll content ($P > 0.05$) from fertilizer addition in the transplanting method while all fertilizer applications in the direct seeding method except organic fertilization increased it. The highest leaf chlorophyll content was 31.7 obtained in samples treated with NPK (20:20:20) and the lowest 28.5 was for the organic fertilizer treated samples. It should be noted that organic fertilizer had the least effect on chlorophyll concentration, especially for the direct sowing method. This indicates that their nutrients are released more slowly than with synthetic fertilizers as they undergo a microbiological process of organic matter mineralization for supplying essential nutrients such as nitrogen, phosphorus, potassium, and magnesium which gradually become accessible to crops. Such microbial processes for nutrient release take longer than the ready access of inorganic fertilizers despite their potential negative environmental impacts from excessive use. The addition of organic fertilizers assist sustainable agricultural practices by boosting microbial activity and raising soil organic carbon (1, 9 and 29).

Table 2: Effect of planting methods and different types of fertilizers on plant height and leaf chlorophyll content of melons (mean n=4).

Fertilizer type	Plant height (cm)		Leaf chlorophyll index (SPAD)	
	Transplanting	Direct seeding	Transplanting	ɾect seeding
Control	37.7 [c]	150.8 [b]	30.2 [a]	29.6 [bc]
NPK (20:20:20)	54.5 [a]	172.6 [a]	32.1 [a]	31.7 [a]
Nanofertilizer (10:12:12)	35.5 [d]	151.6 [b]	30.7 [a]	29.3 [cd]
NPK foliar (20:20:20)	55.0 [a]	138.0 [d]	30.9 [a]	30.5 [ab]
Organic fertilizer	40.5 [b]	145.2 [c]	31.9 [a]	28.5 [d]

Note: Different letters in the same column indicate significant differences between fertilizers ($P < 0.05$).

Results of the ANOVA revealed that all fertilizer-treated samples showed significant ($P < 0.05$) differences in average melon fruit weight and diameters when compared to the control. The highest fruit weight (22.9 kg plot^{-1}) and diameters (44.5 cm) were recorded from nanofertilizer and NPK (20:20:20) application, respectively compared to the lowest at 13 kg plot^{-1} and 22.8 cm in the controls (Figure 3 and 4).

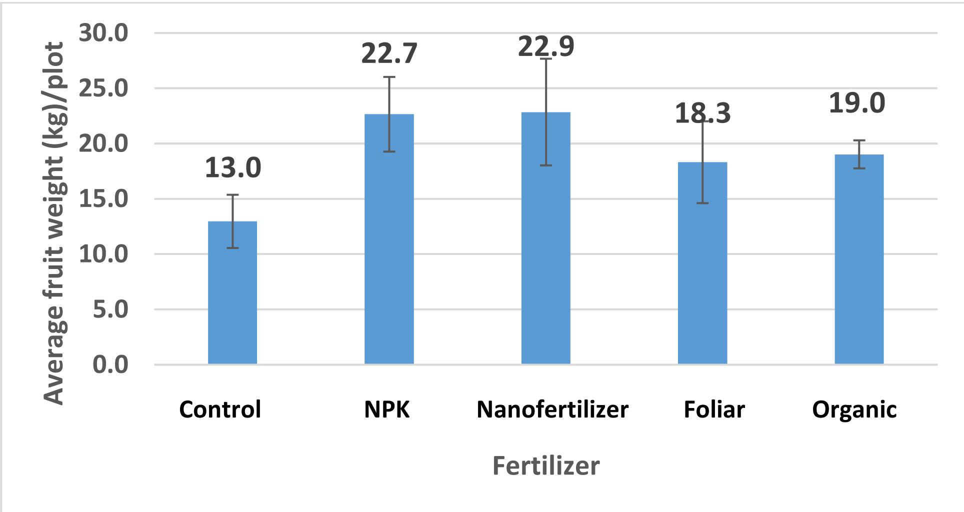

Fig. 3: Average melon fruit weight.

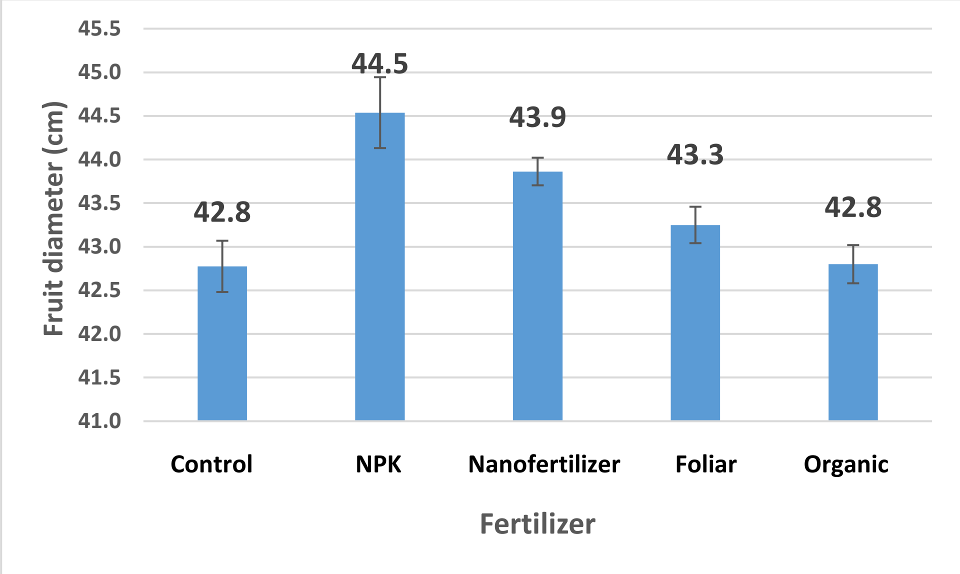

Fig. 4: Average melon fruit diameter.

Furthermore, application of the fertilizers effectively augmented melon fruit weight in both planting methods, with nanofertilizer in direct seeding and organic fertilizer in transplanting showing better results (Table 3). An earlier study noted that "compared to traditional fertilizers, nanofertilizers enhance growth parameters such as leaf areas, dry matter production, chlorophyll content, rate of photosynthesis which leads to higher production and translocation of photosynthesis at different parts of the plant" (13). However, no significant variations ($P > 0.05$) occurred in fruit diameters from the addition of fertilizers to transplanted plants though it did for those in direct seeding plots (Table 3). The effects of the fertilizer were further tested using ANOVA which revealed significant differences with the nanofertilizer application in direct seeding producing the highest fruit weight (35.6 kg $plot^{-1}$) and NPK (20:20:20) the largest fruit diameter (45.4 cm) in the melons at ($P < 0.05$) (Table 3). Nanofertilizers are slow in nutrient uptake, and in this study, plant height was measured 21 days after the first fertilizer application. While there was no effect of nanofertilizer application seen on plant height, fruit yields were higher.

Table 3: Effect of different types of fertilizers on melon fruit weight and diameter based on planting method (mean n=4).

Fertilizer type	Fruit weight (kg $plots^{-1}$)		Fruit diameter (cm)	
	Transplanting	Direct seeding	Transplanting	Direct seeding
Control	6.7 ^{e}	19.3 ^{e}	43.6 ^{a}	42.2 ^{c}
NPK (20:20:20)	13.7 ^{b}	31.6 ^{b}	43.7 ^{a}	45.4 ^{a}
Nanofertilizer (10:12:12)	10.1 ^{c}	35.6 ^{a}	43.7 ^{a}	44.0 ^{b}
NPK foliar (20:20:20)	8.5 ^{d}	28.1 ^{c}	43.1 ^{a}	43.5 ^{bc}
Organic fertilizer	15.7 ^{a}	22.3 ^{d}	43.1 a	42.5 c

Note: Different letters in the same column indicate significant differences between fertilizers ($P < 0.05$).

The application of fertilizers showed variable effects on the sugar content of the melon fruits. NPK (20:20:20) fertilizer application significantly ($P < 0.05$) increased sugar content, producing the highest value at 8.4% (Figure 5) while there was no effect from other fertilizer applications. Also, NPK (20:20:20) fertilizer applications in both direct seeding and transplanting significantly ($P < 0.05$) increased melon fruit sugar content, in contrast to that for all the other fertilizer types (Table 4). The highest sugar content, at 8.8%, was recorded in direct-seeded plants receiving NPK (20:20:20) fertilizer, and the lowest (7.2%) in the control samples grown from seedlings.

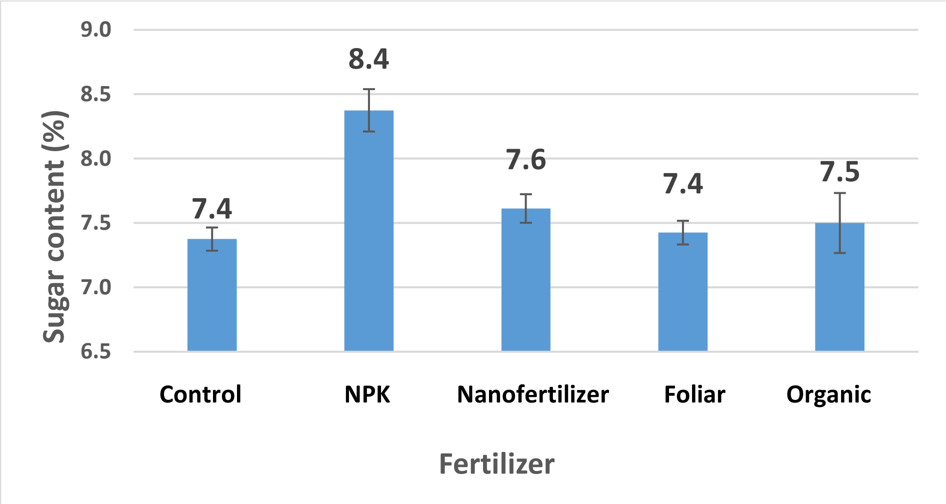

Fig. 5: Average melon fruit sugar content.

Table 4: Effect of different types of fertilizers on melon fruit sugar content under different planting methods (mean n=4).

Fertilizer type	Sugar content (%)	
	Transplanting	Direct seeding
Control	7.2 [b]	7.5 [b]
NPK(20:20:20)	8.0 [a]	8.8 [a]
Nano fertilizer (10:12:12)	7.5 [ab]	7.7 [b]
NPK Foliar (20:20:20)	7.3 [b]	7.5 [b]
Organic fertilizer	7.4 [b]	7.6 [b]

Note: Different letters in the same column indicae significant differences between fertilizers ($P < 0.05$).

Direct seeding and transplanting are two common planting techniques that can have a considerable impact on the development and yield of melons (*Cucumis melo* L.) in greenhouses. Table 5 shows the effect of the two planting techniques on melon plant height, leaf chlorophyll index (SPAD), average yield, diameter, and sugar content. Direct seeding significantly ($P < 0.05$) produced greater plant height, fruit weight, and sugar content for all types of fertilizers, while transplanting produced higher chlorophyll content. In addition, there was no significant ($P > 0.05$) difference in melon fruit diameters between both planting methods. The greatest plant height (172.6 cm), fruit weight (35.6 kg), and sugar content (8.8%) were recorded in direct seeding plots treated with NPK (20:20:20) fertilizer, nano-fertilizer, and NPK (20:20:20) fertilizer, respectively while the lowest were recorded in the nanofertilizer and control transplants at 35.5 cm, 6.7 kg, and 7.2%, respectively. The highest chlorophyll content was 32.1 obtained in transplanted melon and treated with NPK (20:20:20) fertilizer while the lowest at 28.5 was in direct-seeded plants treated with organic fertilizers.

According to the findings of this study, direct sowing resulted in considerably increased plant height, fruit weight, and sugar content, regardless of fertilizer use (Table 5). The growth for directly sown seeds remained undisturbed during their development, leading to better nutrient and water uptake by plants and in improved growth and production outcomes. The direct seeding method allows plants to develop robust roots (3 and 22) and this leads to higher vegetative and reproductive outcomes. Direct sowing manages ecological concerns as well as diseases defense (3). Seedling transplanting, on the other hand, increased chlorophyll content, which might be attributed to the plant height at the time of measurement as the plant applies most of its nutrients for producing flowers and fruits during this stage. The SPAD index values in leaves were closely connected to plant nutrient levels, particularly nitrogen (21).

Table 5: Effect of planting methods on studied parameters (mean n=4).

Fertilizer	Seedling	Direct Seeding
	Plant Height (cm)	
Control	37.7 B	150.8 A
NPK (20:20:20)	54.5 B	172.6 A
Nano fertilizer (10:12:12)	35.5 B	151.6 A
NPK Foliar (20:20:20)	55.0 B	138.0 A
Organic fertilizer	40.5 B	145.2 A
	Leaf Chlorophyll Index (SPAD)	
Control	30.2 A	29.6 B
NPK (20:20:20)	32.1 A	31.7 B
Nano fertilizer (10:12:12)	30.7 A	29.3 B
NPK Foliar (20:20:20)	30.9 A	30.5 B
Organic fertilizer	31.9 A	28.5 B
	Fruit Weight (kg plots^{-1})	
Control	6.7 B	19.3 A
NPK (20:20:20)	13.7 B	31.6 A
Nano fertilizer (10:12:12)	10.1 B	35.6 A
NPK Foliar (20:20:20)	8.5 B	28.1 A
Organic fertilizer	15.7 B	22.3 A
	Fruit Diameter (cm)	
Control	43.6 A	42.2 A
NPK (20:20:20)	43.7 A	45.4 A
Nano fertilizer (10:12:12)	43.7 A	44.0 A
NPK Foliar (20:20:20)	43.1 A	43.5 A
Organic fertilizer	43.1 A	42.5 A
	Sugar Content	
Control	7.2 B	7.5 A
NPK (20:20:20)	8.0 B	8.8 A
Nano fertilizer (10:12:12)	7.5 B	7.7 A
NPK Foliar (20:20:20)	7.3 B	7.5 A
Organic fertilizer	7.4 B	7.6 A

Note: Different capital letters in the same rows show significant differences ($P < 0.05$) between values.

Conclusions

This study showed that type of fertilizers and planting methods affect the growth of melons under greenhouse conditions. In general, the application of NPK fertilizer produced the most favorable outcomes for plant height, chlorophyll content, fruit diameter, and fruit sugar content at 113.5 cm, 31.9 SPAD, 45.4 cm, and 8.8%, respectively. The application of nanofertilizer through direct seeding produced the maximum fruit weight of 35.6 kg $plot^{-1}$. Planting methods are also key factors that determine plant growth and crop yield. Direct seeded plants showed superior outcomes in plant height and sugar content than transplanted seedlings though the latter achieved higher chlorophyll content values. Therefore, the application of NPK fertilizer (20:20:20) and nanofertilizers for greenhouse melon cultivation can be recommended for enhancing the fruit's quality and yield. Further research is needed to determine the optimal fertilizer application rates together with methods to maximize yield production.

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No Supplementary Materials.

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All authors contributed to this study.

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Conflicts of Interest:

The authors declare no conflict of interest.

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Common existing diseases: The plants in this study were exposed to a variety of diseases and pests that had potential to hinder growth and yield (Figure 6). Sap-sucking insects such as aphids, whiteflies, spider mites, and thrips negatively affected plant vigor by stunting and ultimately affecting plant photosynthesis. Downy and powdery mildews and diseases produced by fungi weakened the plants even more, with fewer leaves to produce energy through photosynthesis. Damping-off impaired the seedling stands through reduced and poor establishment. Of these, the nematode was said to have the worst impact, preventing the roots from taking nutrients and water into the plant. While other pests and diseases could be controlled effectively through the use of insecticides, fungicides, and proper agronomic practices, nematode control proved to be more challenging.

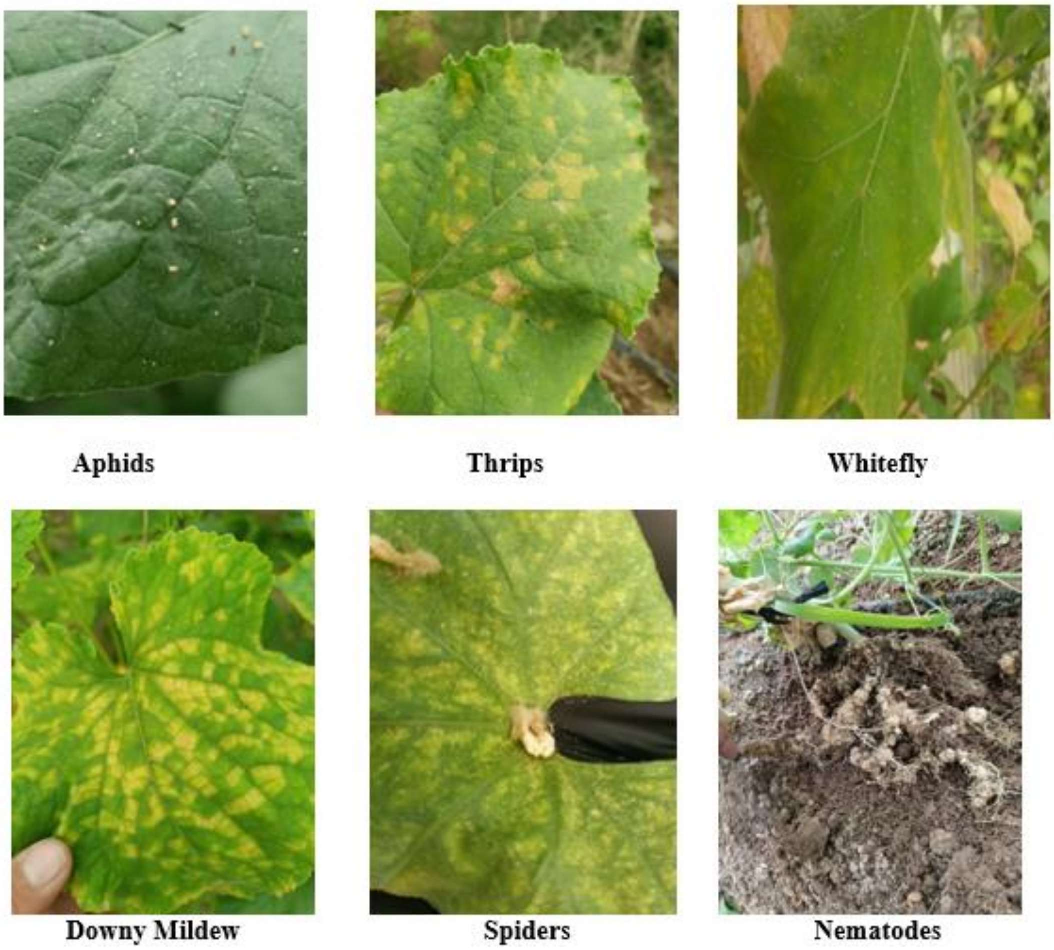

Fig. 6: Common infections of the melon plants prior to the growing season.