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Araştırma (Research)

Assessing Chicken Manure's Competitiveness with Inorganic Nitrogen in Broccoli Production

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Abstract

Objective: This research was undertaken to evaluate the assessment of chicken manure's competitiveness with inorganic nitrogen in broccoli production.

Material and Method: This study was conducted out in field conditions at the experimental area of Atatürk University, Faculty of Agriculture, Department of Horticulture, Erzurum, Türkiye, in 2021 and 2022. Two broccoli cultivars (*Brassica oleracea* var. *italica*, Plenk cvs. 'Burney F_1' and 'Lucky F_1') were used as plant material. While phosphate (200 kg P_2O_5 ha^{-1}) was kept constant in the plots, 1000 kg ha^{-1} (CM-1), 2000 kg ha^{-1} (CM-2), and 4000 kg ha^{-1} (CM-3) chicken manure were applied additionally. The other application was planned according to the recommended dose of nitrogen (Ammonium nitrate (AN), 200 kg N ha^{-1}). Head weight (g), diameter, and length (cm); dry matter contents of head (%); chlorophyll (SPAD); pH and soluble solid content (SSC) (%) content of heads and yield (kg ha^{-1}) were recorded in harvested heads.

Results: The head weight ranged from 81.2 g (control) to 295.4 g (AN). The head diameter and length changed from 6.4 cm and 4.9 cm (control) to 13.9 cm and 13.6 cm (AN), respectively. The highest chlorophyll (SPAD) content (87.6) was consistently observed in the AN application. CM applications were consistently lower than those from AN application for all cultivars and across both years. Furthermore, in CM applications, the highest yield was attained in 2021 at 16820 kg ha^{-1} (CM-3, 4000 kg ha^{-1}), whereas the peak yield of 20618 kg ha^{-1} was recorded in the AN treatment in 2022.

Conclusion: While the yield derived from chicken manure application falls below that achieved through AN application, it is worth noting that, in the context of environmentally sustainable production practices, the utilization of chicken manure at a rate of 4000 kg ha^{-1} can be advocated. As a result, chicken manure at a rate of 4000 kg ha^{-1} can be recommended to broccoli producers for environmentally friendly production.

Key Words: Organic fertilizer, Nitrogen, Broccoli, Yield

Brokoli Üretiminde Tavuk Gübresinin İnorganik Azotla Rekabet Edebilirliğinin Değerlendirilmesi

Öz

Amaç: Bu araştırma, brokoli üretiminde tavuk gübresinin inorganik azotla rekabet edebilirliğinin değerlendirilmesi amacıyla yürütülmüştür.

Materyal ve Yöntem: Bu çalışma, Atatürk Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü Erzurum deneme alanında 2021 ve 2022 yıllarında tarla koşullarında yürütülmüştür. İki brokkoli çeşidi (*Brassica oleracea* var. *italica*, Plenk cvs. 'Burney F_1' ve 'Lucky F_1') bitkisel materyal olarak kullanılmıştır. Parsellerde, fosfor (200 kg P_2O_5 ha^{-1}) uygulaması sabit tutulurken ilave olarak 1000 kg ha^{-1} (CM-1), 2000 kg ha^{-1} (CM-2) ve 4000 kg ha^{-1} (CM-3) tavuk gübresi uygulanmıştır. Diğer uygulama ise önerilen azot dozuna (Amonyum nitrat (AN), 200 kg N ha^{-1}) göre planlanmıştır. Araştırma sonunda, baş ağırlığı (g), çapı ve uzunluğu (cm); başta kuru madde miktarı (%); klorofil (SPAD), pH ve suda çözünebilir katı madde içeriği (SÇKM) (%) içeriği ve verim (kg ha-1) tespit edilmiştir.

Araştırma Bulguları: Baş ağırlığı 81.2 g (kontrol) ila 295.4 g (AN) arasında değişirken, baş çapı ve uzunluğu sırasıyla 6.4 cm ve 4.9 cm'den (kontrol) 13.9 cm ve 13.6 cm'ye (AN) değişmiştir. En yüksek klorofil (SPAD) değeri (87.6) AN uygulamasında belirlenmiştir. CM uygulamaları tüm çeşitler için ve her iki yıl boyunca AN uygulamasından düşük olduğu tespit edilmiştir. Ayrıca CM uygulamalarında en yüksek verim 2021 yılında 16820 kg ha^{-1} (CM-3, 4000 kg ha^{-1}) ile elde edilirken, AN uygulamasında en yüksek verim 20618 kg ha^{-1} ile 2022 yılında belirlenmiştir.

Sonuç: Tavuk gübresi uygulamasından elde edilen verim AN uygulamasıyla elde edilen verimin altına düşşe de, çevresel açıdan sürdürülebilir üretim uygulamaları kapsamında tavuk gübresinin 4000 kg ha^{-1} oranında kullanımının bir çözüm olarak savunulabilir. Sonuç olarak brokoli üreticilerine çevre dostu üretim için 4000 kg ha^{-1} oranında tavuk gübresi önerilebilir.

Anahtar Kelimeler: Tavuk gübresi, Azot, Brokoli, Verim

Introduction

Broccoli (*Brassica oleracea* L. var. *italica* Plenck) belongs to the family Brassicaceae, is widely consumed and produced in many European countries including Turkey, and worldwide because of its high nutrient content, and is an important vegetable for healthy human nutrition (Decoteau, 2000; Ozkutlu, 2020). Brassicas, including broccoli, are typically cool-season crops that thrive in deep, fertile, sandy, or silt loam soils at 6.0 to 6.5 pH. The fertilization requirements of each brassica species are specific to the site and depend on various environmental factors, such as soil type and length of the growing season (Swaider et al., 1992). Broccoli has a high nitrogen (N) requirement and benefits from having fertilizer placed near the plant as it has a relatively small root zone. If there is a deficiency of nitrogen, it can result in decreased yields of broccoli (Welbaum, 2015). In broccoli cultivation, there is a relation between increasing nitrogen doses and higher yields up to a certain threshold (Bowen et al., 1998). In addition to nitrogen fertilization, some trace elements such as B and Mo are also important for yield and quality in broccoli (Moniruzzaman et al., 2007; Ain et al., 2016). In other words, low broccoli yield is an expected outcome when appropriate fertilization management is not implemented. Therefore, essential plant nutrients, especially nitrogen, should be provided since nitrogen plays a crucial role in broccoli production, and broccoli is highly dependent on nitrogen fertilization to achieve high yields (Belec et al., 2001; Babik and Elkner, 2002).

Broccoli growers can satisfy the nitrogen requirements of broccoli by utilizing organic or inorganic sources. Inorganic fertilizers consist of relatively less intricate compounds with concentrated nutrient compositions designed to supply diverse essential nutrients to plants. Conversely, organic fertilizers are characterized by their increased complexity, originating naturally from living organisms such as animals, plants, and birds etc. (Al-Gaadi et al., 2019). Organic fertilizer serves a dual purpose in facilitating plant growth by providing essential macro and micronutrients in readily available forms, while also contributing to the enhancement of soil structure (Korkmaz et al., 2021a). Besides the mentioned features, organic fertilizers allow for higher yield and quality as they promote the root development of broccoli (Abou El-Magd et al., 2005; Abou El- Magd et al., 2006). Moreover, organic fertilizers, particularly those derived from cow and poultry manures, are widely acknowledged as efficient organic fertilizers (Eleroğlu and Korkmaz, 2016). In this context, numerous studies have documented numerous successful instances of cow and poultry manure applications aimed at enhancing soil fertility, nutrient levels, and crop yields (Adekiya and Agbede 2009; Usman, 2015). As with inorganic fertilizers, mineral fertilizers, especially nitrogen, phosphorus, and potassium, influence meristematic activity and improve the yield and plant growth of broccoli and many other vegetables (Abou El- Magd et al., 2006). Nitrogen also plays a pivotal role as a fundamental component of proteins, nucleic acids, chlorophyll, and growth hormones, and it is indispensable during periods of rapid plant growth (Kaymak, 2013).

Since most producers generally aim for high yields not only in broccoli but also in other vegetable crops, they often apply excessive amounts of nitrogen in each production season, especially without soil analysis. However, Korkmaz et al. (2008) reported that extreme use of nitrogen beyond the plant's needs can lead to adverse effects on the environment, particularly pollution of groundwater and related health risks. Moreover, while N promotes plant growth and increases yield, as a result of excessive nitrogen fertilizer application, especially in vegetables, high levels of nitrates can accumulate. These vegetables can pose serious health hazards when consumed by living beings (Hord et al., 2009). Therefore, balanced fertilization of plants is very important to ensure high productivity (Korkmaz et al., 2021b).

While producers want high yields, consumers want to consume healthy crops. Changing preferences of consumers lead producers to use alternative plant nutrient sources. Hence, cow, poultry or other animal manures, both environmentally friendly and a source of N and many nutrients, emerge as an alternative plant nutrient source. As mentioned before, there have been numerous studies on the effects of both organic and inorganic fertilizers on broccoli and other vegetables. However, the number of researches evaluating the competitiveness of chicken, cow, or other animal manures with inorganic fertilizers is insufficient. Since global agricultural production is highly dependent on chemical inputs such as nitrogen and will become even more important in the future, such issues related to N fertilizer continue to attract the attention of scientists from many disciplines (Kılıç and Korkmaz, 2012; Karnez et al., 2013). Therefore, this research was undertaken to determine the assessment of chicken manure's competitiveness with inorganic nitrogen in broccoli production.

Material and methods

This study was conducted out in field conditions at the experimental area of Atatürk University, Faculty of Agriculture, Department of Horticulture, Erzurum, Turkey, in 2021 and 2022. In this study, two broccoli (*Brassica oleracea* L. var. *italica* Plenck cvs. 'Burney F_1 and Lucky F_1') cultivars were used as plant material.

The soil properties of research area were sandy-loamy texture with 6.7-6.9 pH. It had organic matter content 2.25-2.60 %, 21.0-28.7 ppm P, 990.6-995.5 ppm K and 0.002-0.003 % total N in 2021 and 2022, respectively.

Seeds of all cultivars were initially sown in trays filled with a mixture of peat and perlite (75% + 25% v/v) within an unheated glasshouse. Following this, seedlings were meticulously transplanted into 4 m^2 plots located within the experimental area. The sowing dates were July 2, 2021, and June 25, 2022. Seedlings were transplanted with inter-row spacing set at 30 cm and intra-row spacing at 50 cm, adhering to the methodology outlined by Kaymak et al. (2009). Throughout their growth stages, consistent care practices were diligently applied to all plants in each plot, accompanied by drip irrigation for optimal hydration.

All plots were received 200 kg P_2O_5 ha^{-1} (Elkner, 2001; Kaymak et al., 2009) as triple super phosphate. The entire P_2O_5 was evenly distributed and applied to the soil surface by hand before the planting process. It was then thoroughly incorporated into the soil. While P_2O_5 was kept constant in the plots, 1000 kg ha^{-1} (CM-1), 2000 kg ha^{-1} (CM-2) and 4000 kg ha^{-1} (CM-3) chicken manure were applied additionally (Al-Gaadi et al., 2019; Hussain et al., 2020). Also, researchers have suggested that 200 kg N ha^{-1} is usual dose for better yield and quality in broccoli production. Therefore, one of the applications was planned according to the recommended dose of nitrogen. Nitrogen was applied as ammonium nitrate (AN) in two equal parts, half at planting and the other half at the beginning of head formation (Decoteau, 2000; Kaymak et al., 2009).

In the experiment, manual harvesting of the broccoli heads was conducted while the clusters were still in their compact form, prior to the individual flowers reaching maturity (Decoteau, 2000; Kaymak et al., 2009). Head weight, diameter and length; dry matter contents of head (%); chlorophyll (SPAD); pH and soluble solid content (SSC) (%) content of heads and yield (kg ha^{-1}) were recorded in harvested heads. All the measurements were made on randomly selected 14 plants from 28 plants in each plot.

The design of the experiment employed in this study followed a completely randomized block design with three replications. Data obtained from the study were subjected to ANOVA, and the distinctions between means were assessed through Duncan's multiple-range test.

Results and discussion

The effects of CM and AN on the head growth of broccoli cultivars were shown in Table 1. The effect of fertilizers on weight, diameter and length of head were significant ($P < 0.05$ and $P < 0.01$) in both experiment years. The head weight ranged from 81.2 g (control) to 295.4 g (AN). The head diameter and length changed from 6.4 cm and 4.9 cm (control) to 13.9 cm and 13.6 cm (AN), respectively. Moreover, the performance of 'Burney F_1' was better than 'Lucky F_1' in 2021 and 2022. It is generally known that sufficient nitrogen fertilization is necessary for successful broccoli production. Researchers have found that when used alone or in combination, both chicken fertilizer and inorganic nitrogen have a positive effect on broccoli's growth parameters. Indeed, Moniruzzaman et al. (2007) reported that nitrogen fertilization increased the head weight of broccoli. Similarly, Bhattarai et al. (2022) declared that nitrogen significantly increased the head diameter, head weight, and aboveground biomass. Also, chicken manure increased the head diameter of broccoli (Hammad et al., 2019). Furthermore, it was also reported that the most favourable results in terms of head weight and size for broccoli, as compared to the control, were achieved through the combined application of chemical nitrogen and chicken manure (Ewees et al., 2008). To summarize briefly, while the highest head weight, diameter and length were obtained from AN, the lowest values were determined from control in 2021 and 2022. On the other hand, depending on the increase in CM doses (from 1000 kg ha^{-1} to 4000 kg ha^{-1}), the head weight, diameter, and length of the cultivars increased but remained at lower values than those achieved with the AN.

Table 1. The effects of different fertilizers on head growth of broccoli cultivars

	Head weight (g)					
	Burney F_1	**Lucky F_1**		**Burney F_1**	**Lucky F_1**	
Treatments	**2021**		**Mean**	**2022**		**Mean**
Control	140.0 d**	98.9 c**	119.4 D**	128.5 d**	81.2 d**	104.9 C**
CM-1	151.8 cd	139.9 bc	145.8 CD	172.4 c	143.6 c	158.0 BC
CM-2	185.1 c	152.5 bd	168.8 C	207.8 b	164.5 bc	186.2 B
CM-3	240.3 b	175.4 b	207.8 B	210.4 b	174.9 b	192.6 B
AN	284.1 a	276.4 a	280.3 A	295.4 a	244.0 a	269.7 A
Mean	200.2 A**	168.6 B		236.5 A**	161.6 B	
			Head diameter (cm)			
Control	6.9 b**	6.4 c**	6.6 C**	6.6 b**	6.4 b**	6.5 C**
CM-1	7.7 ab	7.7 b	7.7 CC	8.1 b	7.1 b	7.6 BC
CM-2	7.7 ab	8.1 b	7.9 BC	9.9 ab	7.2 b	8.5 BC
CM-3	9.1 ab	8.2 b	8.7 B	10.1 ab	8.8 ab	9.4 B
AN	11.7 a	11.0 a	11.4 A	13.9 a	12.0 a	12.9 A
Mean	8.6 ^{NS}	8.3		9.7 A**	8.3 B	
			Head length (cm)			
Control	6.2 b*	4.9 c*	5.5 C**	7.8 c**	7.3 c*	7.6 D**
CM-1	6.2 b	5.6 bc	5.9 BC	8.8 bc	7.4 c	8.1 CD
CM-2	6.7 ab	5.9 bc	6.3 BC	11.0 ab	7.6 b	9.3 BC
CM-3	7.2 a	6.5 ab	6.9 AB	12.2 a	7.9 a	10.0 B
AN	7.5 a	7.4 a	7.4 A	13.6 a	11.5 a	12.6 A
Mean	**6.8 A****	**6.1 B**		**10.7 A****	**8.3 B**	

** : Significant at $P < 0.01$, * : Significant at $P < 0.05$.

The impact of CM and AN on various parameters, including chlorophyll (SPAD) content, pH levels, soluble solid content (SSC) (%), and head dry matter content (%) of broccoli cultivars, is presented in Table 2. Upon analyzing the SPAD measurements, it is evident that the lowest values were recorded in the control during both experimental years. In contrast, the highest values (87.6) were consistently observed in the AN application. While the SPAD measurements obtained from chicken manure application surpassed those of the control group, they remained lower than those achieved through AN application (Table 2). Tascı and Kuzucu (2023) reported that the highest SPAD value in broccoli was obtained from the application of chemical fertilization (70.20), came after the vermicompost was implemented on vetch pre-planted parcels and single vermicompost parcels. Similarly, Vidigal et al. (2021) reported that the highest SPAD value was obtained when the nitrogen was increased up to 296 kg ha-1, and the SPAD values of broccoli plants ranged between 64.28 and 71.33. In addition, chicken manure and AN application might have elicited a stimulating effect on chlorophyll, primarily attributed to nitrogen's role as a constituent of the chlorophyll molecule and a main component of amino acids. The observation of the lowest SPAD values in the control group further reinforces this hypothesis (Sattel et al., 1998; Tascı and Kuzucu, 2023).

The pH values of the two broccoli cultivars employed in this study were measured as either neutral or in proximity to neutrality. Although the influence of distinct fertilizers and their varying application rates on pH exhibited statistical insignificance during the initial year of experimentation, a noteworthy significance at the 5% level emerged in the second year of the study. In addition, pH values varied between 6.41 and 7.07. Tangkham (2019) reported that the pH of fresh broccoli is 6.70. Indeed, broccoli exhibits a pH range of 6.30 to 6.85, indicating a slightly acidic nature. Notably, broccoli's pH level, it closer to neutrality on the pH scale compared to many other fruits and vegetables (Anonymous, 2023).

In the research, the impact of the treatments on the SSC values demonstrated statistical significance in Burney F_1, yet insignificance in Lucky F_1. In 2021, the SSC values ranged from 6.4% in the CM-1 application to 11.1% in the CM-2 application, representing the lowest and highest values, respectively. Similarly, Nicoletto et al. (2016) stated that SSC values may vary depending on ecotypes.

The impact of the applications on dry matter content was generally not deemed statistically significant, with the exception of Lucky F_1 during the second experimental year. Nevertheless, there are noticeable numerical distinctions among the applications. The highest dry matter content, at 15.4%, was observed in the CM-1 of Lucky F_1 in 2021. Conversely, the lowest dry matter content, at 9.8% (Burney F_1), was recorded in the CM-2 treatment in 2022. According to the report prepared by Kaymak and Kazdal (2022), it has been indicated that the dry matter content of broccoli heads varies according to the cultivars, with the dry matter content of the heads ranging from 5.9% to 12.5%. Moreover, the dry matter content of broccoli is subject to influence by various factors, including plant density, cultivar selection, mulching, nitrogen, seedling age etc. (Everaarts, 1994; Rembialkowska et al., 2003; Yaralı et al., 2007; Kosterna, 2014; Roni et al., 2014).

Table 2. The effects of different fertilizers on chlorophyll, pH, SSC and dry matter content of head of broccoli cultivars

	Chlorophyll (SPAD)					
	Burney F_1	Lucky F_1		Burney F_1	Lucky F_1	
Treatments	**2021**		**Mean**	**2022**		**Mean**
Control	72.3 d**	54.2 b**	63.3 C**	60.9 d**	67.1 b*	64.0 C**
CM-1	81.0 c	60.0 ab	70.5 B	64.2 cd	68.4 b	66.3 BC
CM-2	85.0 b	61.8 b	73.4 B	70.4 bc	70.5 ab	70.4 BC
CM-3	85.2 b	61.5 b	73.3 B	73.5 ab	74.0 ab	73.7 AB
AN	87.6 a	79.7 a	83.6 A	81.7 a	79.4 a	80.6 A
Mean	82.2 A**	63.4 B		70.1 NS	71.9	
			pH			
Control	6.92 NS	6.95 NS	6.93 AB*	6.48 ab*	6.58 b*	6.53 B*
CM-1	6.86	6.96	6.91 B	6.47 ab	6.72 a	6.60 A
CM-2	7.00	7.04	7.02 AB	6.43 b	6.68 ab	6.55 AB
CM-3	7.02	7.07	7.05 A	6.41 b	6.69 a	6.55 AB
AN	6.90	7.00	6.95 AB	6.51 a	6.67 ab	6.59 AB
Mean	6.94 NS	7.00		6.46 A**	6.67 B	
			Soluble solid content (SSC) (%)			
Control	10.5 ab*	7.6 NS	9.0 B*	7.8 b*	9.3 NS	8.6 NS
CM-1	6.4 c	9.1	7.7 C	8.5 ab	8.5	8.5
CM-2	11.1 a	9.0	10.0 A	9.1 a	8.9	9.0
CM-3	9.9cb	8.3	9.1 AB	8.8 a	9.2	9.0
AN	10.1 b	8.7	9.4 AB	8.9 a	9.0	9.0
Mean	9.6 A**	8.5 B		8.6 NS	9.0	
			Dry matter content of head (%)			
Control	13.2 NS	14.3 NS	13.8 NS	10.2 NS	10.8 b*	10.5 B*
CM-1	13.8	15.4	14.6	10.7	12.3 a	11.5 A
CM-2	13.4	14.5	13.9	9.8	11.2 ab	10.5 B
CM-3	13.2	13.7	13.4	10.2	12.1 ab	11.2 AB
AN	13.5	14.5	14.0	10.5	10.8 b	10.6 B
Mean	**13.4 B****	**14.5 A**		**10.3 B****	**11.4 A**	

** : Significant at $P < 0.01$, * : Significant at $P < 0.05$, NS: Not significant at $P < 0.05$

As depicted in Figure 1, the crop yields of different cultivars were significantly influenced by different fertilizers. Significant ($P< 0.01$) differences among cultivars and fertilizers were determined in both experiment years. The highest yield was attained with the application of ammonium nitrate (AN), whereas the lowest yield was observed in the control in both 2021 and 2022. The results indicate that crop yields increased with the rising doses of chicken manure (CM) in both experimental years. However, it is noteworthy that the yields from CM applications were consistently lower than those from AN application for all cultivars and across both years. Furthermore, in CM applications, the highest yield was attained in 2021 at 16820 kg ha^{-1} (CM-3, 4000 kg ha^{-1}), whereas the peak yield of 20618 kg ha^{-1} was recorded in the AN treatment in 2022. It is well-established in the literature that poultry manure tends to yield higher crop yields compared to cow manure (Islam et al., 2010; Al-Gaadi et al., 2019). In line with previous studies, Islam et al. (2010) reported that plants receiving poultry manure exhibited a higher weight.

This phenomenon can be attributed to the beneficial effects of poultry manure on enhancing the plant's physiological processes, consequently leading to increased crop yields (Eleroğlu and Korkmaz, 2016; Khalid et al., 2014). Poultry manure, known for its elevated levels of both macronutrients and micronutrients, undeniably represents a promising organic fertilizer option. However, it is worth noting that the yield obtained with the application of ammonium nitrate (AN) in this study exceeded the yield obtained from the highest dose of chicken manure (4000 kg ha^{-1}) by 35% in 2021 and 40% in 2022. While there is potential to enhance yields through an increase in the chicken manure application dose in this work. Given that excessive utilization of this organic fertilizer may result in detrimental outcomes, such as yellowing of leaves, root deformation, abscission flowers and fruits, burnt roots, and dead plants, it is paramount to exercise utmost caution in chicken manure utilization (Li et al., 2010; Yao et al., 2023).

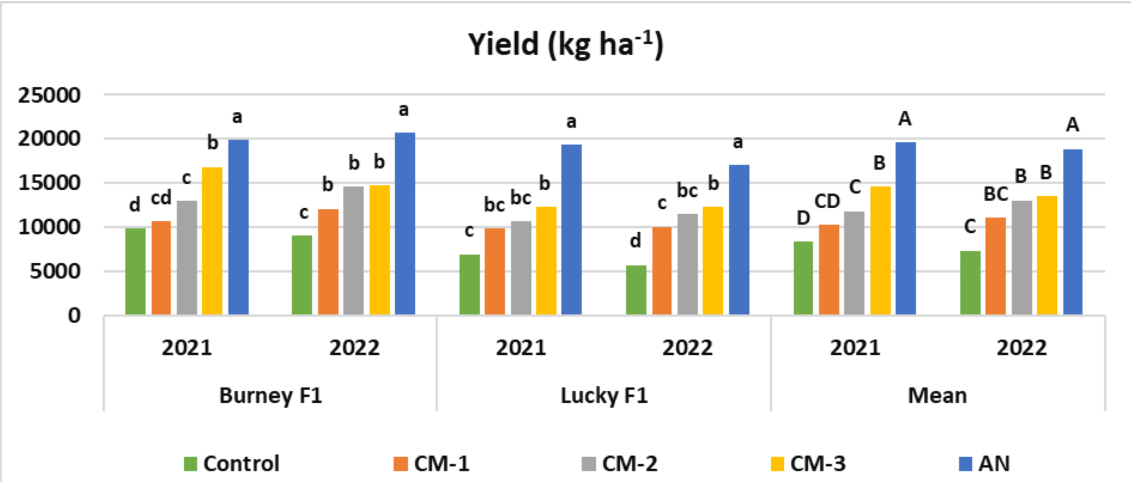

Figure 1. The effects of different fertilizers on yield (kg ha^{-1}) of broccoli cultivars ($P < 0.01$)

Conclusion

In the course of this investigation, which aimed to assess the competitive performance of chicken manure in comparison to inorganic nitrogen in broccoli production, it was ascertained that the application of chicken manure led to a notable increase in yield when compared with the control group. However, it is noteworthy that this increase, while statistically significant, remained inferior to the yield achieved through the utilization of ammonium nitrate (AN). While the yield derived from chicken manure application falls below that achieved through AN application, it is worth noting that, in the context of environmentally sustainable production practices, the utilization of chicken manure at a rate of 4000 kg ha^{-1} can be advocated. Consequently, chicken manure at a rate of 4000 kg ha^{-1} can be recommended to broccoli producers for environmentally friendly production.

Conflicts of Interest

The authors declare no conflicts of interest.

Authorship contribution statement

HÇK: He played a role in providing research materials, designing the experiment, statistically analysing the data, and drafting the article.

ST: She contributed to the performance of laboratory and field studies and the acquisition and evaluation of data.

MK: He contributed to the performance of field studies and the acquisition of data.

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