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Effect of Compost and Synthetic Fertilizer on Soil Fertility, Yield and Nitrogen Use Efficiency of Broccoli Crop in Arid Region of Morocco

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ABSTRACT

Background: Soils in arid regions like Morocco are becoming increasingly degraded and polluted because of the high use of synthetic chemical fertilizers linked to population growth. Organic fertilizers such as compost remain a good alternative to improve soil quality and crop yields. Broccoli is a crop that is beginning to develop in Morocco. It is very nitrogen demanding crop; therefore, it is necessary to know nitrogen use efficiency in broccoli.

Methods: In this field experimental conducted during 2015 at the horticultural complex of Agadir - Agronomy and Veterinary Institute Hassan II, different treatments were tested on broccoli as follows: $T_{C8t/ha}$: compost, 8 t/ha (equivalent 200 kgN /ha), $T_{C12t/ha}$: compost, 12 t/ha (equivalent 300 kg N /ha), T_{SYN}: Synthetic chemical fertilizer (200kg N/ha), T_{C+SYN}: 50% compost, 4t/ha+50% Synthetic fertilizer (equivalent 200 kg N/ha) and T0: control, in order to optimize nitrogen use efficiency of compost and synthetic fertilizer.

Result: Our research showed that the combination of compost and synthetic fertilizer: T_{C+SYN} improved the growth and yield parameters of broccoli; the best main head yield of broccoli was 13.5 t/ha for T_{C+SYN}. Compost improved the chemical properties of soil. Total N content was 266 kg/ha for T_{C+SYN}, 253 kg/ha for T_{SYN}, 244 kg/ha for $T_{C8\ t/ha}$ and 234 kg/ha for $T_{C12\ t/ha}$. For Nitrogen use efficiency, apparent recovery efficiency (ARE) was higher with T_{SYN}: 0.91 followed by T_{C+SYN}: 0.88 followed by $T_{C8t/ha}$ with 0.77 and $T_{C12\ t/ha}$: 0.48.

Key words: Broccoli, Compost, Nitrogen use efficiency, Synthetic fertilizer, Yield.

INTRODUCTION

Broccoli (*Brassica oleracea* var. italica) is a crucifer family (Yoldas *et al*., 2008) like other crucifers, broccoli has a potential anticancer property because it's a rich source of antioxidant, vitamin C, K and E and beta-carotene (Nagraj *et al*., 2020).

In Morocco, broccoli has become a very popular vegetable for consumers. The main difficulty with broccoli is related to high nitrogen needs. Indeed, for a yield of 10 to 20t/ha, the crop needs vary from 150-200 to 350-450 kg ha^{-1} (Thompson *et al*., 2002; Silva *et al*., 2019).

Farmers lack data about the performance of organic fertilizers and nitrogen use efficiency (NUE). NUE is defined as the fraction of nitrogen applied which is absorbed and used by plant (Baligar and Fageria, 2015). Improving a plant's ability to use nitrogen is a key factor in improving yields and chemical soil parameters especially for organic fertilizers where NUE is not available. This parameter was investigated by many researchers (Doberman, 2007; Fageria *et al*., 2008; Sharma *et al*., 2017).

The need for more research in this area is primary at this time (Singh *et al*., 2003). Cereals have been extensively investigated (Yimer *et al*., 2022; Agrama, 2006; Mandolino *et al*., 2018). For vegetable crops, there is a lack of studies on growth and nitrogen uptake for vegetable crops, of which broccoli is one.

In order to optimize nitrogen fertilization, the main objective of this work was to study nitrogen use efficiency of compost and synthetic fertilizer at different doses in broccoli crop.

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MATERIALS AND METHODS

The present study was carried out at the horticultural complex of Agadir-Agronomy and Veterinary Institute Hassan II (30°35′N,-9°47′E, 3 m.a.s.l) in the Souss Massa region in the south of Morocco. The climate was semi-arid. The soil of the plot is sandy-loam type. The initial soil analysis before planting and the irrigation water analysis are presented in Table 1 and 2. The experiment was conducted in a randomized block design with three repetitions per treatment. The treatments studied were as follows: $TC_{8\ t/ha}$: compost, 8 t/ha (equivalent 200 kgN /ha), $TC_{12\ t/ha}$: compost:12 t/ha (equivalent 300 kg N /ha), T_{SYN}: Synthetic

chemical fertilizer on fertigation (200 kg N/ha), T_{C+SYN}: 50% compost, 4 t/ha+50% Synthetic fertilizer (equivalent 200 kg N/ha) and T0: control 50% of fertilizers quantities were applied before planting and 50% were applied at a flowering period near the roots at 50 days after planting (DAP). The synthetic chemical fertilizer was applied by fertigation at a rate of 200 kg N/ha. The compost used in this experiment was rich in organic matter (55%) with a NPK composition of 2.5-3-2.5 and a C/N ratio of 15. The experimental unit was 8.22 m^2 each containing 24 plants. The planting was on 20/03/2015 after tillage with a cover crop. The variety used was Italica. The planting was done with a spacing of 40 cm between two plants and 60 cm between ridges. The plants were irrigated by drip irrigation. The cultivation cycle was 75 days. The impact of fertilizer on soil fertility was determined by soil analysis. Three samples were taken: before crop planting, 50 days after planting and 75 days after planting. For each fertilization program, three soil samples were taken at random. Analyses were performed on: Soil pH was determined in a 1:2.5 soil/water suspension (Jackson, 1973). Soil Organic matter: S OM was determined by the method of Walkley and Black (1934), N content by the method of Kjeldahl. Samples of three plants from each experimental plot were taken at 30 days from the date of transplanting to determine main head yield. Total nitrogen uptake was determined by the Kjeldahl method. The yield and nitrogen uptake parameters are used to calculate agronomic efficiency (AE), agro-physiological efficiency (APE) and Apparent recovery efficiency (ARE) according to the formulas mentioned in the table (Table 3) (Baligar *et al*., 2001; Doberman, 2005).

The data were analyzed using STATISTICA software (version 6.0). The statistical model adopted was one-way analysis of variance (ANOVA). Duncan's test was used to determine significant differences (α=0.05).

RESULTS AND DISCUSSION

Main head yield of broccoli

The main head yield had the highest significant difference (p value 0.001) values for the treatment T_{C+SYN} followed by T_{SYN} (13.50 t/ha) with a high followed by $T_{C8\ t/ha}$ and $T_{C12\ t/ha}$ with 12.92 and 12.75 t/ha respectively. There was no significant difference between $T_{C8\ t/ha}$ and $T_{C12\ t/ha}$. The control recorded the lowest yield with 9.04 t/ha. (Table 4). In our experiment, broccoli produced its maximum yield when the nitrogen fertilizer application rate was 200 kg N ha^{-1}. The same result was observed in California, it was between 200-250 kg N ha^{-1} (Kim *et al*., 2021). Other research in brazil has shown that the optimum content of N ranges from 211 to 373 kg ha^{-1} N (Oliveira *et al*., 2016; Silva *et al*., 2019).

Available soil nutrients

pH decreased throughout the crop cycle for all treatments. This decrease was -7.14% for $T_{C12\ t/ha}$ (Table 5). The decrease in soil pH with compost may be due to the increase of nitrogen in the soil by microorganisms in the form of NH4+ soil ammonium (Zhu *et al*., 2016). NH4+ is the form of N taken up by the plant, so the plant releases H+ which leads to a decrease in soil pH (Hammad *et al*., 2020). Regarding Electrical conductivity, an increase was observed between 50 and 75 DAP for all treatments (Table 5). The highest values at 75 DAP were observed in the compost $T_{C12\ t/ha}$ and T_{SYN} with 2.34 and 2.25 mS/cm respectively. No significant difference was observed between treatments. The possible explanation for the increase in EC may be due to the large amounts of soluble salts and HCO_3 contained in the compost and the decrease of pH in the soil (Abdrabbo *et al*., 2015).

Organic matter increased significantly in all plant's growth stages. Indeed. It increased by 138% and 105% for $T_{C12\ t/ha}$ and $T_{C8\ t/ha}$ respectively. The results are in conformity with (Azuka and Idu., 2021) how found that organic manure improve soil organic matter (Table 5). At 50 DAP, the highest total soil N content was observed for T_{SYN} and T_{C+SYN} with 287.6 kg/ha and 267.2 kg/ha respectively (Table 5). Then, the values decreased to 75 DAP. Statistical analysis revealed significant differences between different treatments tested. The evolution of the total nitrogen content of the soil was influenced by the type of fertilizer. The values dropped at the end of broccoli cycle, which was explained by the high nitrogen requirements of broccoli (Purakayastha *et al*., 2015).

N uptake and nitrogen use efficiency

Total plant N uptake is presented in Table 6. N content for broccoli was 273 kg/ha for T_{SYN} followed by T_{C+SYN}, $T_{C8t/ha}$ and $T_{C12t/ha}$ with 266 kg/ha, 244 kg/ha and 234 kg/ha respectively. The control had the lowest N content with 90 kg/ha (Table 6).

Table 1: Soil analysis results of the trial.

Elements	Units	Values
Organic matter	%	0.7
pH	-	8.4
EC	Mmhos/cm	0.17
CEC	meq/100 g	11.76
N-NO_3-	%	0.22
Available P	mg/kg	9.6
Available K	mg/kg	94
$CaCO_3$	%	3.2

Table 2: Irrigation water analysis results.

Designations	Units	Values
pH	-	7.8
EC (at 25°C)	ms/cm	1.52
CO_3-	meq/l	Traces
K+	meq/l	0.04
Na+	meq/l	1.35
Ca++	meq/l	3.04
Mg++	meq/l	3.7
Cl-	meq/l	10.00
HCO_3-	meq/l	5.4

Table 3: Calculating nitrogen use efficiency.

	Nitrogen use efficiency	Formulas	Designation
EA	Agronomic efficiency	EA= (Gf-Gu)/Na -Gf: yield of fertilized pot (kg) -Gu: yield unfertilized pot (kg) -Na: N amount of nutrient applied (kg)	Increase in yield per unit of N applied ($kg.kg^{-1}$)
EAP	Efficiency-physiological	EAP=(Gf-Gu)/(Nf-Nu) -Gf: yield of fertilized pot (kg) -Gu: yield unfertilized pot (kg) -Nf: amount of N absorbed on fertilized pot (kg) -Nu: amount of N absorbed on unfertilized pot (kg).	Economic output obtained per unit of N uptake ($kg.kg^{-1}$)
ARE	Apparent use coefficient	ARE=(Nf-Nu)/ Na -Nf: amount of N absorbed on fertilized pot (kg) -Nu: amount of N absorbed on unfertilized pot (kg) -Na:amount of N applied (kg)	Quantity of N uptake per unit of N applied

Table 4: Yield parameters of broccoli.

Treatment	Main head yield t/ha
T_{SYN}: 200 N kg/ha of synthetic fertilizer (20-20-20)	13.50a
$T_{C_{8\ t/ha}}$: 200 N kg/ha of compost (2.5-3-2.5)	12.92b
$T_{C_{12\ t/ha}}$: 300 N kg/ha of compost (2.5-3-2.5)	12.75b
T_{C+SYN}: 50% compost+50% syntetic fertilizer (200 Nkg/ha)	13.58a
T0: Control	9.04c
SEm±	0.23

*Values in each column for each treatment followed by different letters are significantly different using Duncan's multiple range test, at 0.05 level.

Table 5: Soil chemical parameters after fertilizer application.

Treatment	pH		EC mS/cm		SOM%		Available N kg ha^{-1}	
	50 DAP	7 DAP	50 DAP	75 DAP	50 DAP	75 DAP	50 DAP	75 DAP
$TC_{8\ t/ha}$: 200 N kg/ha of compost (2.5-3-2.5)	8.02a	7.9a	1.44a	1.65a	1.41a	2.15a	210.8c	113.5b
$TC_{12\ t/ha}$: 300 N kg/ha of compost (2.5-3-2.5)	7.97a	7.7a	1.67a	1.75a	1.42a	2.34a	230.4c	125.1b
T_{C+SYN}: 50% compost+50% syntetic fertilizer (200N kg/ha)	8.12a	7.8a	1.52a	1.63a	1.33a	2.23a	267.2b	136.3a
T_{SYN}: 200 Nkg/ha of synthetic fertilizer (20-20-20)	8.22a	8.02a	0.8b	0.85b	1.41a	2.25a	287.6a	147.1a
T0: Control	8.11a	8.04a	0.9b	1.05b	1.31a	2.01a	77.6d	51.2c
SEm±	NS	1.33	0.07*	0.35*	NS	NS	2.03*	6.01*

DAP- Days after planting; *Significant at P 0.05; NS- Nonsignificant at P>0.05.

Table 6: Total nitrogen uptake after harvesting of broccoli crop and nitrogen use efficiency.

Treatment	Total plant uptake		NUE	
	Nitrogen Kg/ha	AE Kg/kg	APE Kg/kg	ARE%
T_{SYN}: 200 N kg/ha of synthetic fertilizer (20-20-20)	273b	22.30a	24.37b	0.91 a
$T_{C_{8\ t/ha}}$: 200 N kg/ha of compost (2.5-3-2.5)	244b	19.40b	25.19b	0.77 b
$T_{C_{12\ t/ha}}$: 300 N kg/ha of compost (2.5-3-2.5)	234b	12.36c	25.76a	0.48 c
T_{C+SYN}: 50% compost+50% synthetic fertilizer (200 N kg/ha)	266a	22.7 0a	25.79a	0.88 a
T0: Control	90c	-	-	-
SEm±	8.23*	5.02*	NS	0.04*

*Values in each column for each treatment followed by different letters are significantly different using Duncan's multiple range test, at P<0.05 level.

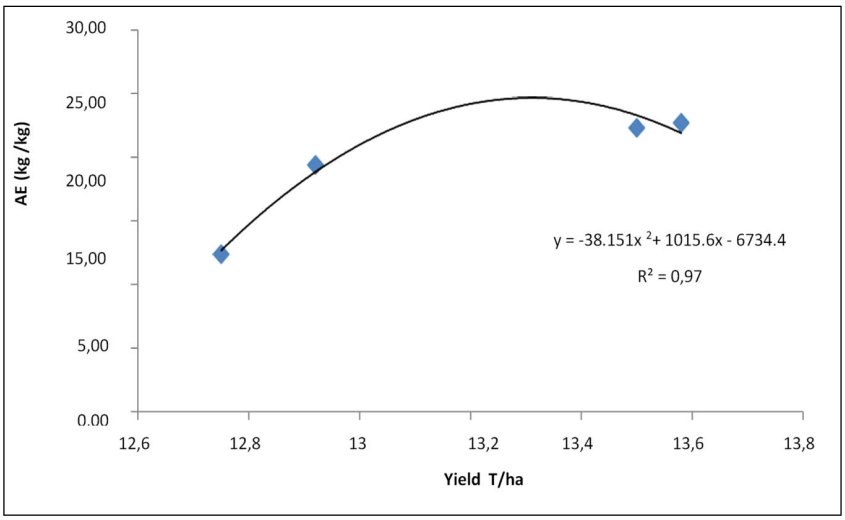

Fig 1: Relation between yield and agronomic efficiency under synthetic and compost treatments.

Agronomic efficiency (AE) was significantly affected by fertilizer type ($p<0.005$). The highest values were recorded by T_{C+SYN} and T_{SYN}: about 22 kg/kg (Table 6). The agronomic efficiency for the synthetic fertilizer was higher compared to compost alone which was in agreement with the results of Musyoka *et al*. (2017) for the cabbage crop, agronomic efficiency of compost 20t/ha gave :14 kg/kg and 20.8 kg/kg for the conventional treatment. High nitrogen input in $TC_{12t/ha}$ decreased AE. This result was in agreement with (Ren *et al*., 2022). A high correlation ($r = 0.97$; $p<0.01$) was observed between AE and yield of broccoli (Fig 1) (Ren *et al*., 2022).

Agrophysical efficiency (APE) varied from 24.37 to 25.79 kg/kg for T_{SYN} and T_{C+SYN} respectively (Table 6). There was a significant difference between compost doses. This result is in agreement with Fageria *et al*. (2014) who found that N rate affects significantly APE.

For apparent recovery efficiency (ARE), which represents the quantity of N uptake per unit of N applied, the values varied from 48% for $T_{C12t/ha}$, 77% for $T_{C8t/ha}$, 88% for T_{C+SYN} to 91% for T_{SYN}. The ANOVA analysis showed significant variations between treatments. The highest value was observed with T_{C+SYN} and T_{SYN} (Table 6). The use of compost and synthetic fertilizers significantly increased N use efficiency (Plaza-Bonilla *et al*., 2021; Widnyana *et al*., 2021). Which it depends on several parameters: soil type, fertilizer, amount applied and climatic conditions (Fageria *et al*., 2014). Reduces the amount of mineral nitrogen provided by 50% (Zhang *et al*., 2021).

CONCLUSION

This study showed the importance of organic fertilization for the organic broccoli production and their impact on soil fertility and nitrogen use efficiency. Using compost with synthetic fertilizer achieved the highest yield and improved growth parameters. The use of 300 kgN/ha dose of compost decreased the main head yield, agronomic efficiency and nitrogen use efficiency. The combination of compost with synthetic fertilizer at 200 kg N/ha achieved satisfactory and efficiently results that are similar or superior to those with synthetic fertilizer alone.

Conflict of interest

All authors declare that they have no conflict of interest.

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