Moroccan Journal of Agricultural Sciences
Vol 1 No 2 (2020): (March 2020)
Crop Production and Environment

Nitrogen use efficiency in organic melon production under greenhouse conditions in South West of Morocco

Kaoutar AOUASS — Department of Horticulture, Hassan II Institute of Agronomic and Veterinary Medicine, Rabat, Morocco

Lahcen KENNY — Department of Horticulture, Hassan II Institute of Agronomic and Veterinary Medicine, Rabat, Morocco

Jamal KRIM — Department of Chemistry, University of Cadi Ayyad, Marrakech, Morocco

Organic melon production under greenhouse condition is widespread in South West of Morocco. However, Organic melon producers are facing serious problems in optimizing nitrogen supply to the crop under greenhouse conditions due to the lack of scientific data on nitrogen use efficiency (NUE). Knowing that for an average yield of 60 T/Ha, melon nitrogen requirements are about 400 kg/Ha. In order to investigate NUE for the most common organic fertilizers used by farmers as compared to a mineral fertilizer (Tm) (20-20-20), an experiment was conducted in Souss Massa region using a randomized complete bloc design with four replicates. Organic nitrogen was applied as compost (Tc): (2.5-3-2.5), (TNPK): Eveilorga (7-4-7), (TNP+K): Altér Orga NP+ Patenkali (8-12-0) + (0-0-30) and (TN+P+K): 10-0-0+ phosphate (0-18-0)+ Patenkali (0-0-30). Nitrogen use efficiency was evaluated on four different parameters: Agronomic efficiency (AE, yield increase per unit of N applied) and physiological efficiency (PE, yield increase per unit of N uptake). Results showed that the form of organic nitrogen applied to the crop has a significant impact on biomass, yield and nitrogen use efficiency. The average yield with organic fertilizers was about 32 T/Ha as compared to the mineral fertilizer (29 T/Ha). Within the organic treatments, a significant difference in yield, AE, and PE were observed.

Keywords: Nitrogen use efficiency, Organic melon, Organic fertilizer, Agronomic efficiency

Introduction

Melon production is rapidly developing in Morocco with an acreage reaching over 12,000 ha. Charente melons are the main variety (produced in greenhouses around Marrakech, Agadir and Dakhla) covering 1,800 ha and mainly aimed at the European market (80% of export is sent to France) (MAPM, 2016).

Organic farming in Morocco is a relatively new sector, the area certified as organic is increasing year after year (Azim and Ramli, 2017). Vegetables represent an important part of exported commodities. Most of the production is geared towards export markets, with the large majority being exported to EU, which is the largest market for agricultural produce and the world’s largest organic market. Organic melon is one of the fast growing export oriented vegetable crops in Morocco after zucchini and tomato. Most the crop is grown under greenhouse (Kenny and Hanafi, 2001).

According to an FAO publication, More than 120 million tones of fertilizer are used in the world (FAO, 2018)with an increase of 1.4% every year. The efficiency of nitrogen use is only 30% on average (Sutton et al., 2013).

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil and plant water management. Use of nitrogen use efficiency may improve yields and soil, but response to fertilizer may be limited by low inherent physical, biological and chemical fertility of soil. Nitrogen use efficiency in crop plants is defined in several ways (Baligar et al., 2001; Dawson et al., 2008; Fageria and Baligar, 2005). In simple terms, N use efficiency is the fraction of fertilizer nutrients removed from the field with the crop harvest (Dawson et al., 2008; Fageria, 2018). Nitrogen use efficiency in cereal grain production is low for a variety of reasons (Raun and Johnson, 1999; Raun et al., 2002). Nitrogen use efficiency of cereals is estimated to be between 42% and 29% depending on weather conditions. There is still a lack of information on the environmental impact, the agronomic value and nutritional efficiency of different organic materials in horticultural plants cropped in Mediterranean conditions. On the light of these considerations, a field research was carried out with the following aims: i) to study the effectiveness of different organic materials application on yield and quality of melon; ii) to evaluate the agronomic performance of these organic materials compared with mineral fertilizer.

Material and Methods

Field study

The research was performed on the experimental farm of the Agronomic and Veterinary Medicine Hassan II Institute, Complex of Horticulture in Agadir located in the Souss-Massa region in the South West of Morocco. The climate is arid, characterized by low rainfall (20 years average = 250 mm), rainfall occur mainly during the period from November to March. The region also characterized with more than 300 sunny days per year and average temperatures varying form 10 to 16 °C in January and from 28 to 32°C in July-august. Soil type is sandy loamy with a pH of 8.01 and EC 0.13 dS cm-1. The soil is middle in organic matter (1.22%) and very poor in terms of total nitrogen content. Table 1 shows the soil texture analysis and table 2 presents the soil chemical analysis.

A randomized complete block design with 6 replicates was adopted. The experimental field measured 387 m2, 6 blocks 11.25 m2 (12.5 m x 9 m), 36 plots 8.1 m2 (9 m x 0.9 m). Six treatments were tested using compost and four other organic commercial fertilizers. The crop was fertilized with six different program using different mixtures of organic commercial fertilizers for a comparison of their effectiveness with that of a synthetic mineral fertilizer of 20-20-20 type show in table 3.

The treatments are: compost: Tc (2.5-3-2.5), a ternary commercial fertilizer TNPK (7-4-7), a mixture of one binary (8-12-0) and one simple (0-0-30) commercial fertilizer TNP+K or a mixture of three simples commercial fertilizer TN+P+K (10-0-0, 0-18-0 and 0-0-30) and Tsyn: mineral synthetic fertilizer (20-20-20).

A muskmelon yield of 60 T/ha removes about 400 Kg/ha of N, 200 kg/ha P2O5and 700 Kg/Ha of K2O (CTIFL, 2010).

Growth and yield parameters

The transplanting of crops was carried out in the first week of May 2015. According to the local planting density of the region melon: 40 cm spacing and 10.000 plants/ha. The variety was Galia. Following transplantation, dead plants were very rare and were replaced. A drip irrigation system was used. The amount of water applied to crops was determined according to crop needs, development stage and weather conditions.

Cumulative yield was assessed. Total weight (Kg) of the fruits in each harvest was added on to the previous amounts in order to determine the cumulative yield during the harvest period. Fruit harvest was performed as fruit maturity progresses and data were consolidated at weekly intervals.

Estimation of the coefficient of nitrogen utilization by plants

The total nitrogen in plant shoot samples were determined after digestion in a mixture of sulfuric ($H2SO4$) and perchloric ($HClO4$) acids. The total nitrogen (N) in the digests was determined by the micro-kjeldahl method (Jackson, 1973). The calculation of the nutrient use efficiency was assessed according to Baligar et al., (2001), Mosier et al., (2004) and Dobermann (2005). The nutrient use efficiency can be expressed by several agronomic indices such as a partial factor productivity (PFP) or nutrient use efficiency in kg crop yield per kg nutrient applied or as an agronomic efficiency (AE) in kg crop yield increase per kg of applied nutrient or Recovery efficiency (RE) which refers to the increase in nitrogen uptake by plants per unit of applied nitrogen (Singh and Shivay, 2003).

These indices were calculated as follow:

Agronomic efficiency of applied nitrogen (AE)

Where GYf is the grain yield of the fertilized plot (kg), GYu is the grain yield of the unfertilized plot (kg) for each replicate and Na is the quantity of N applied as N fertilizer (kg).

Physiological efficiency which denotes the ability of a plant to transform N acquired from fertilizer into grain yield, is defined as grain yield obtained per unit of nutrient uptake. It was computed as:

Where GYf is the grain yield of the fertilized plot (kg), GYu is the grain yield of the unfertilized plot (kg) for each replicate, Nf is the N uptake (grain plus straw) of the fertilized plot (kg), Nu is the N uptake (grain plus straw) of the unfertilized plot (kg) for each replicate.

Partial factor productivity N (PFPN):

Partial factor productivity of applied nitrogen (PFPN) or nitrogen use efficiency (NUE) was calculated according the following equation:

The same formula was used with P and K nutrients.

Statistical Analyses

The various observations were analyzed using Minitab software, according to analysis of variance and multiple comparison of means (Tukey test).

Results and discussion

The soil pH ranged from 8.07 to 7.55. The pH of the soil receiving synthetic fertilizers was lower as compared to other treatments (Figure 1a). This result can be explained by acidification and salinization caused with synthetic fertilizer (Zhang et al., 2015). The electrical conductivity (EC) of soils ranged from 0.240 to 0.211 dS/m (Figure 1b). The EC values are generally low in the experiment site compared to the EC values of the other regions in Souss Massa (El- Oumlouki et al, 2014). The values of the soil organic matter content (OM) before organic fertilizer were close to 1% (Figure 1c). At 23 DAP, an increase in OM of about 70% has been observed with organic fertilizer. They were significantly higher than the control and the Tsyn. The control remained stable in their OM content.

Effect of amendments on soil organic carbon (SOC)

Application of organic fertilizer significantly increased soil organic carbon content in comparison to untreated controls ($p<0.05$) (Figure 2). The highest value of SOC content was 18 g kg-1 with compost application. There were no statistical differences between TNP+K and TN+P+K treatments compared to the untreated control ($p<0.05$). These results were related to the higher amount of organic carbon applied with treatments TC and TNPK (about 6 and 4 t ha-1, respectively). Moreover, TC and TNPK showed a slower decomposition of organic matter that resulted in an increase of SOC. This result was in agreement with Butler and Hooper (2010), Graham, Haynes and Meyer (2002). The application of compost to land has the potential to enhance soil and biomass carbon sequestration (Zhang et al., 2012), characterized mainly by high molecular carbon compounds such as lignin and polyphenols, more resistant to biodegradation (Fersi et al., 2018). This would indicate that recalcitrant C compounds were accumulated in soil with compost and TNPK application

Effects of amendments on soil organic nitrogen (SON)

Treatments Tc and TN+P+K showed the highest soil organic nitrogen content (SON) at the end of the trial. On the other hand, no statistical differences were observed among unamended control (T0), TNPK and TNP+K treatments (1.1 g kg-1) (Figure 3). The highest SON content in the treatment amended with compost may be due to the low mineralization rate of their organic matter. This result was in agreement to what reported by Kavdir and Killi (2008) who observed that organic nitrogen content in soil was important with vegetal compost.

Effect of amendments on soil mineral nitrogen (SMN)

Soil mineral nitrogen increased significantly with Tsyn applications in comparison to TNPK, TN+P+K and Tc. Soil NO_3^- content in plots amended with TNPK and Tsyn were 45.5 mg kg-1 and 57.4 mg kg-1, respectively (Table 3). Statistically, no differences were found between treatments Tsyn and TNP+K as well as among treatments Tc, TNPk and unamended control ($p<0.05$). This effect can be associated to the low C/N ratio of Tsyn (5.6), compared to TNPK and compost (19.8 and 20, respectively) (Table 3), that favors the highest mineralization rate. On the other hand, all plots showed almost the same soil ammonium content ($p<0.05$). Further, the general lower content of ammonium in comparison to nitrate can be attributed mainly to the nitrification and a partial volatilization of the NH_4^+.

Total yield

Application of organic fertilizer was effective in increasing the melon yield. No significant yield difference was found between chemical fertilization and organic fertilization. There were significant increases ($P<0.05$) in the yield of melon under different organic fertilizers compared to the control treatment and Tsyn. The highest values of melon yield were obtained with Tc and Tsyn (32 and 29 T/ha) followed by TNPK (25 T/ha), and TN+P+K (25 T/ha), respectively (Figure 4). Tsyn and Compost were at par and significantly superior to that obtained with TNPK, which in turn was significantly superior to no nitrogen T0 (control). Some researchers have already reported that organic fertilizer has a variety of benefits, including faster growth early in the season and improved plant growth. On average, number of fruit per plant produced during the crop cycle was significantly higher with Tc thus significantly increasing the average when compared to the TNPK, TNP+K and Tc which was not statistically different.

Effect of amendments on melon quality

The results of melon fruits characteristics are shown in Table 4. Fruit qualitative parameters respect the minimum values established by the EU Regulation n° 1615/2001 (size > 8 cm; weight > 250g; total soluble solids (TSS) > 8 °Brix). Regarding total sugar and fruit firmness, no significant difference was found between treatments. On average a Brix of 8.4 degrees was recorded and 3 kg/cm² regarding firmness (Table 4).

Fertilizer partial factor productivity

PFP is the most important index of total economic outputs for the crop relative to the use of all Nitrogen, phosphorus or potassium sources (Doberman, 2007; Hawkesford, 2012).The results showed that the average PFP for N (PFP-N), P (PFP-P) and K (PFP-K) were 75, 154 and 44 kg/kg, respectively. The higher PFP-N, PFP-P and PFP-K was observed with Tc: 140.3 and 80.0 kg/ kg. This was closely related to the yield improvement. The PFP-K values were mostly lower than the values or PFP-P and PFP-N, and the annual average values ranged from 26.0 kg/kg to 80.0 kg/kg (Table 5).

Nitrogen use efficiency

Agronomic nitrogen efficiency (AE) varied from 29.0 to 120.0 kg kg-1. The highest and lowest value of AE was related to Tc and TN+P+K, respectively. There were significant differences between treatments. Addition of phosphorus and potassium alone caused decrease AE (Figure 5).

The higher AE resulted in a higher yield. As high AE was generated with complete form of organic fertilizer (compost, Evelorga) it is probably due to the higher nutrient availability and high nutrient content of N. However, AE in central highlands of Kenya for potatoes is reported to be lower than this study, ranging from 2 to 23 kg produce per kg of applied N with organic low input and organic high input (Musyoka et al., 2017) and this could be attributed to crop type, soil type (Ghosh et al., 2015; Kumar et al., 2015), amount of N applied and type of fertilizer (Fageria and Baligar, 2005; Ladha et al., 2005).In comparison with mineral fertilizer, a little effects on agronomic efficiency (increment of yield/unit of applied N) was observed which was also reported by Agel et al., (2008).

Physiological efficiency (PE) values ranged from 548 to 1078 kg kg-1. The PE value was greater in TNPK than other treatments. Lowest value of PE was seen in TN+P+K. There were significant differences between treatments. In Tc, Addition of compost caused an increase of PE (Figure 6). Agro-physiological efficiency (APE) values varied from 583 to 1067 kg kg-1. The APE was less in TN+P+K than other treatments. The highest value of APE was related to addition of organic fertilizer in complete form NPK, especially compost and organic NPK fertilizer. There were significant differences between treatments.

Conclusion

This study compared the effect of organic and inorganic fertilizer in terms of AE, PE, PFP and related parameters. Generally, organic melon with a high yield potential has high AE, especially in sandy loam soil such as that of this study site.

Our study showed that the application of organic and mineral fertilizer effectively enhances the AE of organic melon, as the maximum AE was observed with the compost.

The higher AE resulted in a higher yield, as a high AE was generated with complete form of organic fertilizer (compost, Evelorga), probably due to the higher nutrient availability and high nutrient content of N.

References

Azim K., Ramli H. (2017). Country report: Organic Agriculture development in Morocco, ISOFAR. http://isofar.org/isofar/index.php/2-uncategorised/284-isofar-and-inra-morocco-organize-the-1st-eu-north-african-conference-on-organic-agriculture-eu-nacoa.

Baligar V.C. and Fageria N.K. (2015). Nutrient Use Efficiency in Plants: An Overview, in Nutrient Use Efficiency: From Basics to Advance, Springer India, 1–14.

Baligar V.C. Fageria N.K. and He Z.L. (2001). Nutrient use efficiency in plants, Commun. Soil Sci. Plant Anal. 32: 921–950.

Butler J., Hooper P. (2010). Down to Earth: An illustration of life cycle inventory good practice with reference to the production of soil conditioning compost. Resour. Conserv. Recy., 55: 135–147.

Dawson J.C., Huggins D.R., Jones S.S. (2008). Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. Field Crop. Res., 107: 89–101.

Dobermann A. (2007). Nutrient use efficiency – measurement and management. In: Krauss, A., Isherwood, K. & Heffer, P. (Eds.), IFA International Workshop on Fertilizer Best Management Practices (Proceedings), 7–9 March 2007; Brussels, Belgium (pp. 1-28). Paris, France: International Fertilizer Industry Association.

El Oumlouki K., Moussadek R., Zouahri A., Dakak H., Chati M., El Amrani M. (2014). Study of physic-chemical quality of water and soil in the region Souss Massa (Case perimeter Issen), Morocco. Journal of Materials and Environmental Science, 5: 2365-2374.

Fageria N.K., Santos A.B. (2018). Comparative Efficiency of Nitrogen Sources for Lowland Rice Production. Comm. Soil Science and Plant Analysis, 49: 515-525.

FAO (2018). Global report on food crises. Food Security Information Network, Rome, FAO.

Fersi M., Mbarki K., Gargouri K., Mechichi T., Hachicha R. (2018). Assessment of organic matter biodegradation and physico-chemical parameters variation during co-composting of lignocellulosic wastes with Trametes trogii inoculation. Environ Eng. Res., 24: 670-679.

Ghosh B.N., Singh R.J., Mishra P.K. (2015). Soil and input management options for increasing nutrient use efficiency. Nutrient Use Efficiency: from Basics to Advances, 17-27.

Graham M.H., Haynes R.J., Meyer J.H. (2002). Soil organic matter content and quality: effects of fertilizer applications, burning and trash retention on a long-term sugarcane experiment in South Africa. Soil Biol. Biochem., 34: 93–102.

Hawkesford M. (2012). The Diversity of Nitrogen Use Efficiency for Wheat Varieties and the Potential for Crop Improvement. Better Crops, 96: 10-15.

Kavdir Y., Killi D. (2008). Influence of olive oil solid waste applications on soil pH, electrical conductivity, soil nitrogen transformations, carbon content and aggregate stability. Bioresour. Technol., 99: 2326–2332.

Kumar R., Parmar B. S., Walia S. and Saha S. (2015). Nitrification Inhibitors: Classes and Its Use in Nitrification Management, in Nutrient Use Efficiency: from Basics to Advances, Springer India, 103–122.

Ladha J.K., Pathak H., Krupnik T.J., Six J. and Kessel C.V. (2005). Efficiency of fertilizer nitrogen in cereal production: Retrospect’s and prospects. Advances in Agronomy, 87: 85-156.

Musyoka M.W., Adamtey N., Muriuki A.W. and Cadisch G. (2017). Effect of organic and conventional farming systems on nitrogen use efficiency of potato, maize and vegetables in the Central highlands of Kenya, Eur. J. Agron., 86: 24–36.

Rattunde H.F., and Frey K.J. (1986). Nitrogen harvest index in oats: Its repeatability and association with adaptation. Crop Science, 26: 606–10.

Raun W.R., Solie J.B., Johnson G.V., Stone M.L., Mullen R.W., Freeman K.W. et al. (2002). Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. Agron. J., 94: 815–820.

Raun W.R. and Johnson G.V. (1999). Improving nitrogen use efficiency for cereal production. Agron. J., 91: 357-363.

Sutton M.A., Bleeker A., Howard C.M., Erisman J.W., Abrol Y.P., Bekunda M., Zhang F. S. (2013). Our nutrient world. The challenge to produce more food & energy with less pollution. Centre for Ecology & Hydrology.

References