Industrial Crops and Products 37 (2012) 264–269

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

An integrated fertilization system of canola (*Brassica napus* L.) production under different crop rotations

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ARTICLE INFO

Article history:
Received 24 August 2011
Received in revised form 1 December 2011
Accepted 5 December 2011
Available online 11 January 2012

Keywords:
Biofertilizer
Canola
Compost
Farmyard manure
Oil

ABSTRACT

Cropping systems in farmland areas of Iran are characterized by continuous cultivation of crops with consumption of chemical fertilizers leading to serious soil erosion and fertility decline. Information regarding the simultaneous evaluation of crop rotation and fertilization on the canola is lacking. Hence, field experiments were conducted during 2007–2010 using split–split plot design. Three crop rotations: chickpea, sunflower, wheat, and canola (R1); green manure, chickpea, green manure, wheat, green manure and canola (R2); canola, wheat, and canola (R3) were used as main plots. Sub plots were consisted of six methods of fertilization including (N1): farmyard manure (FYM); (N2): compost; (N3): chemical fertilizers; (N4): FYM + compost and (N5): FYM + compost + chemical fertilizers; and control (N6). Four levels of biofertilizers consisted of (B1): phosphate solubilizing bacteria (PSB); (B2): *Trichoderma harzianum*; (B3): PSB + *T. harzianum*; and (B4): without biofertilizers were arranged in the sub-sub plots. Results showed that green manure application in canola rotation (R2) increased grain yield and nutrient uptake. Combined application of FYM, compost and chemical fertilizers (N5) elevated the nitrogen uptake rate and grain oil yield. Simultaneous use of PSB and *T. harzianum* (B3) resulted in the increase of nitrogen and sulfur contents of grain. R2 rotation with regard to its biological and environmental efficiencies accompanied with FYM + compost and B3 (PSB + *T. harzianum*) is suggested as a low input system to obtain a more sustainable and productive farming in canola.

1. Introduction

Winter oilseed rapeseed (*Brassica napus* L.) is the dominant oilseed crop in northwest region of Iran and is often grown followed by winter wheat. It ranks third in terms of world oilseed production after soybean and groundnut crops. Considering canola as a recent introduced crop to the region, the optimized rotation and nutrient management can lead to the sustainable improvement of canola farms. Biodiversity and management of soil fertility are essential elements of sustainable food production systems (Doran et al., 1988). Applying green manure to soil is considered a suitable management practice in every agricultural production system because of increasing sustainability cropping system by reducing soil erosion, improving soil physical properties, and increasing soil organic matter and fertility levels (Tejada et al., 2008). Several investigations have confirmed that canola following cereal crops yielded substantially lower than compared to growing after legumes (Christen and Sieling, 1995). A sustainable, organic farming needs to be self-sufficient in nitrogen (N) through the fixation of atmospheric di-nitrogen (N_2) by legumes (Berry et al., 2002), recycling of crop residues (green manures) (Elfstrand et al., 2007) and the application of organic and biological fertilizers (Ravindran et al., 2007; Mohammadi et al., 2011). Fertilization is one of the soil and crop management practices, which exert a great influence on soil and grain quality (Chander et al., 1998; Kamkar et al., 2011). Compared to cereals, canola requires a higher amount of nutrients. Proper use of fertilizer sources is required to optimize the economic yield (Mason and Brennan, 1998) and to minimize the potential for environmental pollution (Aufhammer et al., 1994). Substantial amounts of nutrient elements can be provided by previous crop residues and organic fertilizers. Compost and farmyard manure (FYM) are organic sources of nutrients, which increase soil organic matter and enhance soil quality.

Phosphorus is one of the major essential nutrient elements and is world's second largest mineral required for plant growth and development. There are global concerns about the energy and costs involved in mining the rock phosphate and its transport to fertilizers manufacturing sites, and their transport to farm fields. Phosphate solubilizing bacteria (PSB) are known to increase phosphorus uptake resulting in better growth and higher yield of crop plants (Rudresh et al., 2005).

Abbreviations: FYM, Farmyard manure; PSB, Phosphate solubilizing bacteria.

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doi:10.1016/j.indcrop.2011.12.023

Trichoderma spp. have long been known as effective antagonists against soil-borne plant pathogenic fungi (Kumar and Mukerji, 1996) and promote vegetative growth in plants. The study of combining these organisms and organic manures is of great potential value to organic agriculture in order to avoid application of chemical fertilizers. The present research is aimed at studying an integrated fertilization system using a combination of biofertilizers and organic manure including green manure, compost and farmyard manure, PSB and *Trichoderma* fungi on oil yield and quality of canola under different crop rotations

2. Materials and methods

2.1. Site specification

The trial was conducted from 2007 to 2010 at the Agricultural Research Center of Sanandaj (ARCS), Kurdistan province, the northwest region of Iran (35°16 lat. N; 47°1 long. E, 1405 m above sea level). The soil type is sandy loam (100 g/kg clay, 460 g/kg silt, and 440 g/kg sand) with a water holding capacity of 272 g/kg. Some of the initial soil chemical properties in the surface layer (0–25 cm) were pH 7.4 (1:2.5 in water), 1.2% OM, 0.21% total N, 7.4 mg/kg Olsen P, and 238 mg/kg extractable K^+ (NH_4Ac).

2.2. Experimental design

The experimental design was a split–split plot based on randomized complete block design with three replications. Main plots were three crop rotations including (R1): chickpea (*Cicer aritenium* L.), sunflower (*Helianthus annuus* L.), winter wheat (*Triticum aestivum* L.), and canola (*Brassica napus* L.); (R2): green manure, chickpea, green manure, winter wheat, green manure, and canola; (R3): canola, winter wheat, and canola. The green manure used was a combination of hairy vetch (*Vicia panunica* L.) and barley (*Hordeum vulgare* L.). Sub plots were six strategies of supplying the basal fertilizer requirements of canola including (N1): 15 t FYM/ha; (N2): 10 t compost/ha; (N3): 100 kg triple super phosphate/ha + 150 kg Urea/ha + 50 kg potassium sulfate/ha; (N4): 7.5 t FYM/ha + 5 t compost/ha, (N5): 7.5 t FYM/ha + 5 t compost/ha + 50 kg triple super phosphate/ha + 75 kg Urea/ha + 25 kg potassium sulfate/ha and (N6): Control (without fertilizer). Four levels of biofertilizers including (B1): *Bacillus lentus* + *Pseudomonas putida*; (B2): *Trichoderma harzianum*; (B3): *B. lentus* + *P. putida* + *T. harzianum*; and (B4): not using biofertilizers as control were arranged in sub-sub plots.

2.3. Preparation and performance

Expectation values of base fertilizers were determined according to soil test analysis. Three soil samples were taken from the upper 15 cm layer of the soil profile of each plot and were analyzed for physical and chemical characteristics for fertilizers recommendation (Carter, 1993). The canola seeds, according to arrangement of sub-sub plots were treated with *T. harzianum* isolate T_{39}, *B. lentus* isolate P_5 and *P. putida* isolate P_{13}. PSB and *Trichoderma* fungi were obtained from Iranian Soil and Water Research Institute and the compost was obtained from Compost Municipal Factory of Sanandaj. The FYM and compost were also analyzed for chemical and nutrients properties (Table 1). FYM, compost and chemical fertilizer were added to plots before sowing canola. Main plot size was 10 m × 30 m and spaces between main plots were three meters. In third year canola seeds were planted on September 10. After canola harvesting, seeds were collected to determine the canola grain yield per unit area. Area harvested was 5 m^2 (2 m × 2.5 m) for each sub-sub plots. Moisture contents of canola grain were adjusted to 9% at harvest stage.

2.4. Crop measurements

The nitrogen content of the matured seeds was determined by Microkjeldahl method (Bremner, 1996) and sulfur content was determined by method of Chesnin and Yien (1950). The canola seed oil was extracted with petroleum ether using Soxhlet (AOAC, 2002). The composition of fatty acids was determined by gas chromatography (model 8700, Perkin-Elmer, USA) equipped with a flame ionization detector (FID). A 2 m long stainless steel packed column containing 3% OV-17 on chromosorb (WHP 100–200 mesh) was used. Helium was the carrier gas. Injector and detector temperatures were 240 °C and the oven temperature was maintained at 215 °C for 30 min. The carrier gas flow rate was 30 ml/min. Individual fatty acid content was calculated on the basis of the area under the chromatography peak, and then each fatty acid was expressed as a percentage of the total fatty acid content (Ahmad and Abdin, 2000).

2.5. Statistical analyses

The data collected in this study were subjected to analysis of variance (ANOVA) using PROC GLM of SAS statistical program (SAS Institute, 2002). Mean comparisons were conducted using Fisher's LSD using SAS software (SAS Institute, 2002).

3. Results and discussion

3.1. Grain nitrogen and sulfur

Analysis of variance showed that crop rotation had significant effects on nitrogen (N), sulfur (S), and grain nitrogen to sulfur ratio (N/S). Comparison of means (Table 2) showed that the highest rate of nitrogen and sulfur and the lowest grain N/S were obtained in the R2 rotation. Nitrogen to sulfur ratio is considered as a genetically inherited trait, but it is also affected by nutritional and environmental factors (Zhao et al., 1998). A slightly increase of this ratio for plants is desirable, but high increase in canola can cause symptoms of sulfur deficiency in the plant and reduce yield (Barker and Pilbeam, 2007).

The results of the present study indicated that grain yield in R2 rotation was higher than other rotations. R2 rotation (green manure, chickpea, green manure, wheat, green manure and canola) also possessed the lowest N/S. These findings are in agreement with those of Zhao et al. (1997) who also observed the reduction of grain yield due to the N/S ratio increment in canola. Sulfur plays an important role in the metabolism of fatty acids, amino acids having sulfur and leaf chlorophyll; hence, sulfur increasing can lead into grain yield and oil quality improvement (Barker and Pilbeam, 2007). Therefore, one of the reasons for reducing grain yield in the R3 rotation is attributed to increase of the N/S ratio. Application of green manure before canola planting provides nitrogen and other nutrition elements. Nitrogen fixation by vetch, which was released

Table 1
Chemical characteristics of FYM and compost applied to the soil.

Characteristic	pH	N (%)	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Cu (ppm)
FYM	7.45	0.74	0.49	0.31	745	1100	8	25
Compost	7.20	0.70	1.15	0.51	1950	1890	45	295