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RESEARCH ARTICLE

Effects of Various Agroindustrial Wastes on Nutrition Yield and Quality of Canola (*Brassica napus L.*)

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Abstract:

Introduction:

Canola is an important agricultural crop generally grown for oil and biofuel generation.

Materials and Methods:

The agroindustrial solid wastes of oregano and cumin wastes were used in a vegetation experiment to determine their effect on the nutrition, yield and quality of the canola plant (*Brassica napus* L.) The experiment was performed on 12 plots of 6 m^2 and was conducted with four treatments of composted oregano and cumin wastes, mineral fertilization and control in three replications. Physical and chemical properties and macro-micro nutrients were determined in the soils at the beginning and the end of the experiment.

Results and Discussion:

The leaves showed sufficient levels of N, P, K, Ca, Mg and low sufficient levels of Na, Fe, Cu, Zn and Mn. The boron content of the leaves was insufficient. Manganese and B were affected significantly by the applications. The applications did not affect plant height, shoot and carob number per plant, and seed numbers per carob significantly. Statistically, the highest number of plants per m^2 was observed in the plots to which cumin wastes were applied, and these plots also showed the maximum yield.

Conclusion:

Seed yield, protein and oil percentages were not affected significantly by the applications.

Keywords: Agroindustrial wastes, Canola, Soil Fertility, Yield, Quality, Manganese.

1. INTRODUCTION

Canola is the most important biomass besides sunflower, palm and soybean with respect to biodiesel production. Because of relatively high nutrient requirement, great attention should be paid to fertility management in canola production [1]. Increasing the input of mineral nutrients plays an important role in yield, quality and nutrient use efficiency. Canola requires more nitrogen than cereal crops. According to Kaefer *et al.* [2], although grain yield and protein and oil contents in seeds were not affected by the N sources, increasing N rates increased protein contents and reduced oil contents in canola seeds. Smith *et al.* [3] reported that large amounts of N fertilizer reduced the oil content but enhanced the protein content in canola and found a negative correlation between oil concentration and protein content. Phosphorus is required in smaller amounts than N for plant growth but is very important for energy transfer. For optimizing canola production, P fertilization is recommended [1]. Potassium is involved as a plant nutrient in

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numerous physiological and biochemical processes. In general, its uptake by oilseed rape is greater than that of any other nutrient [4]. Due to the rapid redistribution of K within the plant, K deficiency symptoms may not necessarily be observed in the field and the fundamental importance of K may not be recognized [5]. Cheema *et al.* [6] studied the influence of K levels on two canola cultivars and found that oil content progressively decreased with an increase in K level. According to a soil K test index in China, K fertilizer is recommended to increase soil fertility and achieve high seed yield in winter oilseed rape [7]. Jankowski *et al.* [8] found increased yield in winter oilseed rape seeds with foliar application of boron and fertilizer, which improved the nutritional value of seed but lowered its feed value. According to Gao *et al.* [9], the remaining rapeseed meal can be used after extraction as an organic fertilizer for the cropland or as a source of animal feed.

In cases of insufficiency of the organic matter in the soil, the use of organic residues, by-products or wastes is gaining high importance in improving soil fertility and plant nutrition. Several agro-industrial residues have relatively high concentrations of nutrients, and these could regulate the physical and chemical properties of the soils. Many studies have been performed on the effect of agro-industrial wastes on soil fertility and plant nutrition. Some of these are Singh *et al.* [10], who used pressed sludge, molasses and rice husks, Steponavicius [11], who used the sludge of milk production, Stepkowsha *et al.* [12] with a compost of olive oil sludges, Elmacı *et al.* [13] with various solid and liquid agro-industrial wastes, and Kılıç *et al.* [14], who used tobacco wastes. According to Elmacı *et al.* [15], the application of production residues of cumin and oregano to the soil increased the microbiological activity of the soil most with cumin wastes, but mineral fertilizer application had no effect on microbial biomass and activity in the soil. The use of medicinal and aromatic plants such as cumin and oregano is widespread in the world in many branches of industry: Turkey supplies 70% of the world's oregano and has many processing factories [16]. However, the waste from these factories causes problems with respect to storage requirements. The aim of this study was to evaluate these wastes for the nutrition of canola plants.

2. MATERIALS AND METHODS

A field experiment was conducted with canola plants (*Brassica napus L.*) using solid wastes which had been separately composted for 7.5 months from a medicinal and aromatic plant factory in the Ödemiş district of İzmir province in Turkey. Three samples were taken from each composted waste type (cumin and oregano) as specified in Table **1** and analysed for their physical and chemical properties. In this manner, the pH, total soluble salts [17], organic matter [18] and total N [19] contents of the wastes were determined. For the determination of macro- and micronutrients, the samples of wastes were wet digested (HNO_3:$HClO_4$; 4:1) [20]. In the extractions, the content of P was determined by colorimeter [21], that of K, Ca and Na by flame photometer and that of Mg, Fe, Cu, Zn, Mn by AAS (Atomic Absorption Spectrometry) [22]. For the determination of B content, extraction with hot water was performed on the soil and on the wastes after digestion of the samples at 500^{o}C. The boron content of the extracts was measured using a 1:1 dianthrimid indicator with colorimeter [20, 23].

Physical and chemical properties and macro- and micronutrients were determined in the soils of the field experiment at the beginning of vegetation. In these soils, total soluble salt [24], $CaCO_3$ [25], organic matter content [26], texture [27] and total N content [18] were analysed in addition to pH [28]. The amounts of available K, Ca and Na in the soil were determined by flame photometer, and Mg was determined by AAS [28] after extraction with 1 N NH_4OAc [29]. Available P was measured by colorimeter in an extract with distilled water [30]. Available Fe, Cu, Zn and Mn were extracted with 0.05 M DTPA+TEA and measured by AAS [31].

The field experiment was conducted using coincident block design with three blocks and four plots of 6 m^2 each per block. Additionally, mineral fertilizer and control plots were also arranged in order to compare the cumin and oregano wastes. The composted wastes (40 t ha^{-1}) were incorporated into the soil before planting at a depth of 15-20 cm. Mineral fertilizers were applied at recommended doses of 200 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 200 kg K_2O ha^{-1}. One third of the N doses and the whole of the P and K were given as 15:15:15, NH_4NO_3 (33 N % W.B.) and in the form of K_2SO_4 at planting, another 1/3 was given at the beginning of vegetation, and the third N dose was given two weeks after the second application as NH_4NO_3. *Brassica napus* (*L.*) was planted in each plot in eight rows with 30 cm between rows and 5-7 cm above the rows. At the end of vegetation, soil samples were taken from all plots at a depth of 0-20 cm and changes in physical and chemical properties and macro- micro nutrients were determined.

Leaf samples were taken at flowering and analysed for all macro- and micronutrient contents by the methods described above.

At the end of the vegetation, the plants were harvested. Plant height, plant number per m^2, shoot and carob number per plant, seed number per carob and seed yield per m^2 and ha were determined as growth and yield parameters. Crude protein and oil percentages were obtained as quality parameters. Total N content in seeds was analysed according to the modified Kjeldahl method [19] and multiplied by 6.25 to obtain the crude protein percentage [32]. The oil percentage of the air-dried seeds directly was determined with the Oxford Newport Analyser (NMR).

Statistical analyses were performed using the Tarist 4.01 DOS [33] package. The data was analysed by one factor coincidental block design, and variance analysis was applied. Mean values were separated according to the Least Significant Difference method at $p \leq 0.01$.

3. RESULTS AND DISCUSSION

Table **1** shows the physical and chemical properties and macro- and micronutrients of the composted wastes used in the experiment. The pH values of the wastes were slightly alkaline (7.4) for the oregano wastes and medium alkaline (8.3) for the cumin wastes. The organic matter content and all of macro- and micronutrients except Fe and Na contents were higher in the cumin wastes than in the oregano wastes. Table **2** represents the physical and chemical properties and macro- and micronutrient content of the experimental soil.

Table 1. Some physical and chemical properties and macro- and micronutrients of composted wastes used in the canola experiment.

–	–	–	%				%					%	mg kg^{-1}					
–	pH	EC (dS m^{-1})	Soluble Salt	Organic Matter	Organic C	C/N	N	P	K	Ca	Mg	Fe	Na	Cu	Zn	Mn	B
Cumin Wastes	8.3	18	1.2	42	24	12	2.0	0.39	1.9	1.9	0.28	0.19	500	36	97	157	5.5
Oregano Wastes	7.4	15	1.0	32	19	12	1.6	0.21	1.4	1.4	0.16	0.23	500	25	57	125	3.0

This soil was neutral, had no salinity problem, was low in $CaCO_3$ and organic matter, and had a loamy sandy texture. Regarding macronutrients, the total N and available Mg contents of the soil were at a medium level, while according to Güneş *et al.* [34], available K and Ca were low, and according to Chapmann and Pratt [35], P levels were high. Akdemir *et al.* [36] found 11.4 mg kg^{-1} of available P in this region's soils and Oktay *et al.* [37] found 12.5 mg kg^{-1}. The contents of Fe, Cu and Zn were found to be good and sufficient and Mn was insufficient, while boron was below the toxic level of 0.5 mg kg^{-1} given by Güneş *et al.* [34].

Table 2. Physical and chemical properties and macro- and micronutrient contents of experimental soil (0-20 cm depth).

Properties	Units	Depth
pH		7.05
Total Soluble Salt	%	< 0.03
$CaCO_3$	%	0.66
Sand	%	79
Loam	%	17
Clay	%	4
Texture		Loamy-sand
Organic Matter	%	1.09
Total N	%	0.05
Available P	mg kg^{-1}	8.41
K	mg kg^{-1}	110
Ca	mg kg^{-1}	830
Mg	mg kg^{-1}	139
Na	mg kg^{-1}	14.4
Fe	mg kg^{-1}	14

(Table 2) contd.....

Properties	Units	Depth
Cu	mg kg^{-1}	1.2
Zn	mg kg^{-1}	1.4
Mn	mg kg^{-1}	3.6
B	mg kg^{-1}	0.08

Changes in the soil's physical and chemical properties such as macro and micronutrients contents after the vegetation period of the canola plant are shown in Table **3**. The applications had no effect on the pH and total soluble salt content of the soil compared with the beginning of vegetation. A similar effect was also demonstrated by Elmaci *et al.* [38] with cumin and oregano wastes applied for cotton nutrition. The fact that the total soluble salt values in the control and oregano and cumin treatments were equal indicated that the wastes carried no risk with respect to salinity. During the vegetation, the $CaCO_3$ and organic matter percentages of the soils increased by at least twofold in nearly all treatments. Statistical differences were observed between the applications in respect of the $CaCO_3$ ($p<0.01$) and organic matter ($p<0.05$) percentages of the soils. As expected, oregano and cumin wastes had statistically the most increasing effect on the organic matter percentages of the soil. Elmaci *et al.* [38] found the highest organic matter increase in soils planted with cotton to which oil-free oregano had been applied. Bahtiyar [39] stated that organic wastes of different origins had recently been used as a soil amendment to increase or regulate organic matter content in the soil. At the end of vegetation, only the total N percentage of soils was affected significantly by the applications. Cumin wastes have the most pronounced effect on the total N content of the soil, while oregano wastes also have a statistical increasing effect on it. Although not at a significant level, other macronutrients such as P, K, Ca, Mg and Na were higher in the soil of plots to which oregano or cumin wastes had been applied than in the others. The highest Ca content after harvest of the soils to which oregano was applied is well correlated with the highest $CaCO_3$ percentage of these soils. Elmacı *et al.* [38] found Ca levels with a significance of higher than $p<0.01$ in soils with cotton to which oregano wastes had been applied. Compared with the beginning of vegetation, waste applications increased the N, P, K, Mg and Na content of the soils, while available Ca content decreased considerably at the end of the vegetation. With respect to the micronutrients of the soil, no significant differences could be obtained between the treatments Table **3** but the levels of Mn and B were increased in all treatments as compared with the beginning of the experiment (see Table **2**).

Table 3. Various physical and chemical properties and macro- and micronutrient content of treated soils (0-20 cm depth) after harvest.

-	-	%				A v a i l a b l e (mg kg^{-1})									
Treatments	**pH**	**Total soluble salt**	**$CaCO_3$**	**Organic Matter**	**Total N**	**P**	**K**	**Ca**	**Mg**	**Na**	**Fe**	**Cu**	**Zn**	**Mn**	**B**
Control	7.0	< 0.03	1.35 ab	1.97 b	0,071 b	8	145	162	221	35	14	1.8	2.2	8	0.59
Mineral Fertilizer	6.7	< 0.03	1.34 ab	2.18 ab	0.062 b	11	159	246	201	34	19	2.0	2.5	12	0.61
Cumin wastes	7.0	< 0.03	1.17 b	2.78 a	0.097 a	13	215	290	274	41	15	2.0	1.9	12	0.96
Oregano wastes	7.0	< 0.03	1.63 a	2.83 a	0.081 ab	12	252	426	215	40	15	1.6	2.1	10	0.82
Minimum	6.7	< 0.03	1.17	1.97	0.062	8	145	162	201	34	14	1.6	1.9	8	0.59
Maximum	7.0	< 0.03	1.63	2.83	0.097	13	252	426	274	41	19	2.0	2.5	12	0.96
LSD	ns.	ns.	0.31**	0.671*	0.023*	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.

Values are the average of three replicates LSD: Least Significant Difference Method ns.: Non significant *: $p \leq 0.05$ **: $p \leq 0.01$ Means for treatments followed by the same letter are not significantly different.

Table **4** shows the macro- and micronutrient contents of leaves at the flowering stage. Bergmann [40] gave sufficient values in percentages for canola leaves at early flowering as N: 4.0 to 5.5, P: 0.35 to 0.70, K: 2.8 to 5.0, Ca: 1.0 to 2.0 and Mg: 0.25 to 0.40, and the leaves in the experiment indicated sufficient levels of these elements. Reuters and Robinson [41] determined 0.02 to 0.54% Na as sufficient and 0.7 to 1.1% as high.

Table 4. Macro- and micronutrients of leaves at the flowering stage (dry weight basis).

-	%					mg kg^{-1}					
Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**Na**	**Fe**	**Cu**	**Zn**	**Mn**	**B**
Control	4.69	0.51	3.3	1.0	0.64	358	74	5	21	37 b	0.77 c
Mineral Fertilizer	4.87	0.53	3.0	1.1	0.63	339	85	6	30	58 a	4.53 b
Cumin wastes	4.42	0.57	3.7	0.9	0.66	309	81	4	22	39 b	12.05 a
Oregano wastes	4.93	0.57	3.7	0.9	0.55	277	79	5	26	37 b	11.72 a
Minimum	4.42	0.51	3.0	0.9	0.55	277	74	4	21	37	0.77
Maximum	4.93	0.57	3.7	1.1	0.66	358	85	6	30	58	12.05
LSD	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.	8.93**	3.754**

Values are the average of three replicates LSD: Least Significant Difference Method ns.: Non significant **: $p \leq 0.01$, Means for treatments followed by the same letter are not significantly different.

Compared with the values given by Reuter and Robinson [41] of Cu: 4 to 25, Zn: 22 to 49, Mn: 31 to 250 and B: 22 to 54 mg kg^{-1}, the leaves were at low sufficient levels with respect to Cu, Zn and Mn, and at less than sufficient levels with respect to boron. Only Mn and B were affected significantly by the applications. Manganese levels were higher in plots fertilized with minerals, and boron levels were higher in plots to which wastes had been applied. According to Grant and Bailey [1], micronutrient deficiencies in canola are not common, but might occur on specific soils.

The yield parameters of the canola plants at harvest can be seen in Table **5**. Plant height was between 152 and 157 cm and was not significantly affected by the applications. Statistically, the highest plant number per m^2 was observed in the plots to which cumin wastes were applied. Shoot numbers per plant were between 6 and 7, carob numbers were between 100 and 130, and seed numbers per carob were between 250 and 293. These were not significantly affected by the treatments. Seed yield varied between 2.3 and 3.3 t ha^{-1}, and the highest value was obtained from the plots with cumin wastes, although this was not significant. Akdemir *et al.* [42] registered a 2.0 to 3.5 t ha^{-1} canola yield which varied with variety, soil and climatic conditions. According to Marquard [43], canola yield was approximately 3.6 t ha^{-1} in Germany. Canola yields were improved especially by fertilization with sidedress N, soil-applied S and foliar-applied boron [44]. Increases in canola yield have been reported with B, Zn and Cu application [1]. Ebrahimian *et al.* [45] reported that N and Zn had a significant effect on plant weight, pod number per plant and seed yield. In winter, rape seed yield increased by more than 10% with boron as well as a combination of B and Cu fertilization [46].

Table 5. Yield parameters of canola at harvest.

Treatments	Plant Height (cm)	Plant Number m^{-2}	Shoot Number per Plant	Carob Number per Plant	Seed Number per Carob	Seed Yield		
						(g m^{-2})	(kg da^{-1})	(t ha^{-1})
Control	152	55 b	6	100	293	232	232	2.3
Mineral Fertilizer	152	64 ab	6	102	250	236	236	2.4
Cumin wastes	157	74 a	6	129	279	326	326	3.3
Oregano wastes	152	54 b	7	130	255	265	265	2.6
Minimum	152	54	6	100	250	232	232	2.3
Maximum	157	74	7	130	293	326	326	3.3
LSD	ns.	15.037*	ns.	ns.	ns.	ns.	ns.	ns.

Values are the average of three replicates LSD: Least Significant Difference Method ns.: Non significant *: $p \leq 0.05$ Means for treatments followed by the same letter are not significantly different.

Seed protein and oil contents are shown in Table **6**. Seed crude protein was 25 to 27% and seed oil was 41 to 43%, and they were also not significantly affected by the applications. Kolsarıcı [47] and Kıllı [48] reported 40 to 45% seed total oil in canola plants and Akdemir *et al.* [42] reported 38 to 50%. According to Akdemir *et al.* [42], seed crude protein in canola is approximately 16 to 24%. Nitrogen fertilizer application increased the protein contents but decreased the oil contents of rape seed; however, these parameters were not significantly influenced by the application of P and K fertilizer [49].

Table 6. Seed protein and oil content of canola.

Treatments	Total N (%)	Crude Protein (%)	Total Oil (%)
Control	4.1	25	43
Mineral Fertilizer	4.4	27	41

(Table 6) contd.....

Treatments	Total N (%)	Crude Protein (%)	Total Oil (%)
Cumin wastes	4.1	26	42
Oregano wastes	4.0	25	43
Minimum	4.0	25	41
Maximum	4.4	27	43
LSD	ns.	ns.	ns.

Values are the average of three replicates LSD: Least Significant Difference Method
ns.: Non significant

According to Lucas *et al.* [50], N and S fertilization increased canola yield without significantly altering the content of oil and crude protein. Oil content in winter rapeseeds increased after the highest S dose (60 kg S ha^{-1}), as well as after application of B and Cu fertilization [46].

CONCLUSION

When agroindustrial solid wastes of oregano and cumin wastes were used in a canola vegetation experiment, the leaves indicated sufficient levels of N, P, K, Ca and Mg. Manganese and boron content of the leaves, which was below sufficient levels, was significantly affected by the applications. Maximum yield and statistically the highest number of plants per m^2 were observed with cumin wastes. The applications did not significantly affect seed yield, protein or oil percentage. In conclusion, as stated in most of the literature, quality characteristics such as the oil and protein content of canola were not very much affected by applications and environmental conditions, and the genetics of this plant plays a more important role in this respect.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest, financial or otherwise.

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