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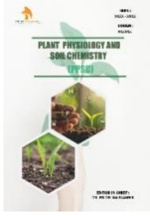

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RESEARCH ARTICLE

THE COMBINED EFFECT OF THE TILLAGE DEPTH AND COMPOST APPLICATION ON CALCAREOUS SOIL AGGREGATES AND THE YIELD OF INTERCROPPED FABA BEAN WITH WHEAT

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ABSTRACT

Calcareous soils crusting and low organic matter (OM) content are key problems restrict their management and productivity. The aim of this study is to assess the role of tillage at different depths along with the compost application for improving some characteristics of the calcareous soil as well as the yield, and its components of the intercropped faba bean with wheat (1:1 ratio). A field experiment was carried out at the Nubaryia Agricultural Experimental Station through the two successive winter seasons (2019/2020) and (2020/2021) in a split-plot design with three replicates. The main factor (F1) was the plough depth treatments: Chisel plough (20 cm depth) and subsoiler (40 cm depth) one time and twice. The sub-factor (F2) was the applied compost (C1= 5.95 and C2= 11.9 tons ha^{-1}). A control without additions was involved. The wheat and fababean were sown in a 1:1 intercropping ratio mixed with the surface layers by hatchat under a surface irrigation system and the recommended agronomic practices were followed. The tillage treatments combined with increasing the rate of the applied compost have increased the total stable aggregates (TSA), the aggregation index and aggregation degree in the surface and subsurface soil layers (0 – 20 cm, 20 - 40 cm) as well as the saturated hydraulic conductivity (Ks) for both seasons. The water stable aggregates (WSA) distribution revealed that the 8-2 cm aggregates are the abundant size especially in the surface soil layers. The 40 cm depth subsoiler twice treatment combined with the compost rate C2 resulted in the maximum OM for both seasons. The relative maximum OM increase (%) compared to the corresponding control was by 32.3 and 26.7% in the 0 – 20 cm soil layer and by 64.9 snd 60.0% in the 20 – 40 cm soil layer. For the compost rate C2, the most significant relative increase in the wheat grains yield (kg ha^{-1}) was by 74.8% with the plowing two times at 40 cm depth, while for the faba bean seeds yield (kg ha^{-1}) it increased by 145.5% with the 20 cm depth plowing. The studied treatments were effective for improving the calcareous soil properties and productivity.

KEYWORDS

Aggregation degree; Aggregation index; Calcareous soil; Compost; Inter cropped faba bean with wheat; Tillage practices

1. INTRODUCTION

The main land utilization problems of the calcareous soils are crusting of the surface soil layers, cemented condition of the subsoil layers along with the low organic matter (OM) content, and nutrients availability. Tillage and fertilization are two important and common farming practices significantly change the characteristics of the particle size composition of the soil aggregates and influence the aggregates/soil organic carbon (SOC)/microorganisms interactions. The frequent tillage with chemical fertilizers deteriorated the polymerization of clods and reduced the formation and stability of aggregates that exposes the protected SOC to the microbial attack. Oppositely, the reduced tillage with organic manure application improves the formation of SOC-enriched aggregates (Zhao et al., 2021; Niu et al., 2022).

The soil tillage could be considered among the important factors that affecting the soil physical and chemical properties and tillage practices may be contributed 20% of the among crop production factors (Voorhees et al., 1984; Khurshid et al., 2006). Soil tillage can affect the stability and formation of soil aggregates by disrupting the soil structure. Frequent tillage deteriorates the soil structure and weakens the soil aggregates, making them susceptible to decay (Panagea et al., 2022; Zheng et al., 2018). Reduced tillage practices showed the potential for enhancing soil physical quality only through improving aggregate stability (Obalum et al., 2019; Bartlová et al., 2015).

The soil structure significantly affects its support for the plant growth, cycle of carbon, nutrients and the absorption, retention and movement of water. The agricultural management practices can lead to both short/long-term effects on the role of soil structure stability. Soils of a higher stability are more resistant to the soil degradation that may be attributed to the increased soil OM. The soil susceptibility to the external load of destructive forces can be indicated by assessing the soil aggregate stability. Soil aggregation preserves the biologically active and biochemically rich topsoil against loss from cultivated fields. Soil aggregate means a naturally occurring unit of soil structure consisting of particles of sand, silt, clay, organic matter, and coarse fragments held together by the natural cohesion of the soil.

Aggregate Stability is the measured ability of a soil to hold together and

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Table 7: Structure Parameters (Aggregation State, Aggregation Index, Aggregation Degree) as Affected by Plough Depth and Applied Compost in Calcareous Soil for The Two Seasons 2019/2020 And 2020/2021

Plough depth	Treatments	Soil depth (cm)	Aggregation state*		Aggregation index		Aggregation degree	
			19/20	20/21	19/20	20/21	19/20	20/21
Chisel (20 cm)	Control	0-20	39.5	36.76	0.77	0.71	32.03	28.07
	C 1		47.55	44.97	1.28	1.20	38.93	37.83
	C 2		46.19	43.52	1.42	1.35	38.97	37.18
Subsoiler (40 cm one time)	Control		39.13	36.89	0.55	0.50	31.92	30.22
	C 1		49.65	47.28	1.41	1.34	41.65	41.65
	C 2		49.59	46.94	0.90	1.21	49.59	48.68
Subsoiler (40 cm twice)	Control		41.32	40.29	0.78	1.05	27.81	31.82
	C 1		42.92	40.05	0.68	0.84	45.39	42.22
	C 2		50.12	48.15	0.90	1.18	45.37	46.71
Subsoiler (40 cm one time)	Control	20-40	37.16	36.92	0.52	0.58	31.86	36.81
	C 1		50.13	48.33	0.92	0.66	53.68	55.47
	C 2		49.17	46.92	1.32	0.63	55.87	52.26
Subsoiler (40 cm twice)	Control		42.23	40.65	0.75	1.13	28.01	29.84
	C 1		48.37	46.08	0.82	1.37	38.87	38.91
	C 2		45.55	44.73	1.03	0.99	38.24	43.13

* **Total water stable aggregates TSA**

The obtained results in Table 7 and Figure 1 revealed that structure parameters aggregation state, aggregation stability index, aggregation degree and differences in mean weight diameter (ΔMWD) as affected by plough depth and applied compost in calcareous soil for seasons (2019/2020) and (2020/2021). The results appeared that aggregation index as well as aggregation degree intensified with increasing the rate of applied compost under-utilizing Chisel plow (20 cm). Whereas, adding compost with the rate of C1 or C2 under utilizing subsoiler (40 cm one time) or subsoiler (40 cm twice) caused a marked increase of aggregation index and aggregation degree in surface soil layer (0 – 20 cm) and subsurface soil layers (20 – 40 cm). This increment may be attributed to enhancement in aggregation process and production suitable structure parameters, resulted in utilizing tillage practices which increase the aggregates susceptibility to formation and the role of organic materials as binding agent as mention above. These results are an accordance with the results obtained (El-Maaz, Enshrah et al., 2010).

3.2 Saturated Hydraulic Conductivity (Ks)

Many soil properties are known to influence soil hydraulic conductivity such as soil texture, soil structure, soil porosity and organic matters. (Selem, 1983). The obtained results in Figure 2 revealed that soil hydraulic conductivity (m/day) as affected by plough depth and applied compost in calcareous soil for seasons(2019/2020) and (2020/2021). Data indicate that the usage chisel plow (20 cm), subsoiler for 40 cm one time and sub soiler for depth 40 cm twice intensified (Ks) in the surface soil layer (0-20cm). These finding are in agreement with (Millard et al., 1995)

The increase in (Ks) values might be attributed to tillage practice that improved the soil water penetration and consequently water intake rate increased. Under using Chisel plow (20 cm), the Ks was increased with increasing the rate of applied compost., Figure 2. This increment may be due to the role of organic materials in improving soil aggregation status in the soil. This can explained as, in a well aggregates could give a wide range of pore sizes withand between aggregates. Under-utilizing Subsoiler for depth 40cmone time or subsoiler 40cm twice, soil hydraulic conductivity (Ks) intensified in subsurface soil layers (20-40 cm) with increasing the rate of applied compost. This increment may be due to breaking up the impervious layers by subsoiler plough which led to improve water movement into the soil.

Additionally, the role of organic materials in improving soil aggregation status in soil as mention above .In general, (Ks) decrease by increasing soil depth. These results are in agreement with (El-Sedfy et al., 2007).

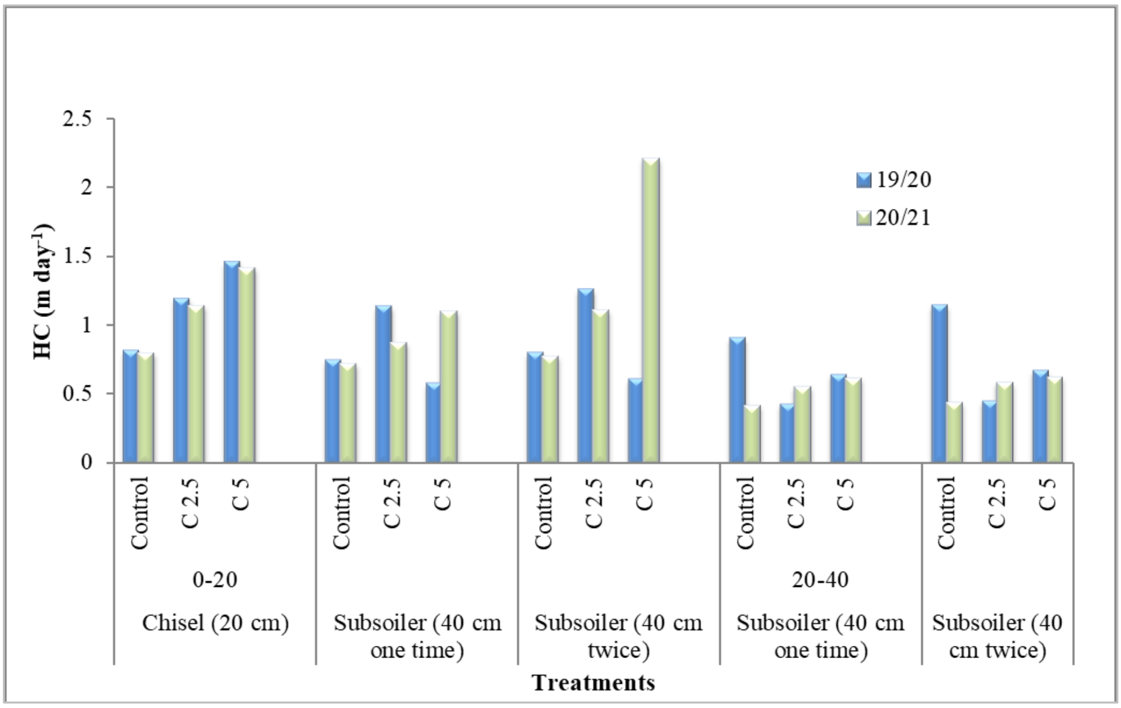

Figure 2: Hydraulic conductivity (m day-1) under the effect of plough depth and applied compost in calcareous soil for the two seasons 2019/2020 and 2020/2021

3.3 Effect of The Tillage Treatments and The Applied Compost on The Organic Matter Content (OM, %) and The Available Macronutrients in Soil

3.3.1 Effect on the OM (%)

The results presented in Table 8 indicate that the OM content in soil was increased as the rate of the applied compost increased under using Chisel plough (20 cm), Subsoiler (40 cm one time) and/or Subsoiler plow (40 cm twice). This can be attributed to the high OM content in the applied compost (Table 2). The maximum value of the OM in both studied soil layers (0 – 20 cm and 20 – 40 cm) was obtained by applying the higher rate of the compost (C2) along with the subsoiler plowing at 40 cm depth two times. The relative maximum increase (%) compared to the corresponding control was by 32.3 and 26.7% in the 0 – 20 cm soil layer and by 64.9 snd 60.0% in the 20 – 40 cm soil layer for the seasons 2019/2020 and 2020/2021, respectively. This is in agreement with results obtained previously (El-Sedfy et al., 2005; El-Sedfy et a1., 2007).

3.3.2 Effect on The Soil Available N, P, and K

Expectidly, the general trend is that the available N, P, and K (mg kg^{-1}) have increased in soil as the compost application rate increased for the different tillage treatments as revealed by Table 8. However, the maximum relative increases (%) compared to the control were recorded for the top soil layer (0 – 20 cm) since it is received the main applied doses of the compost. This is often due to the decomposition of OM contained in the compost and releasing nutrients in the available form (Awad et al., 2003). The C2 compost rate with plowing at 0 – 20 cm depth has increased the available N by 58.2 and 63.0%, P by 70.6 and 77.0%, and K by 22.6 and 24.8% for the seasons 2019/2020 and 2020/2021, respectively, in the 0 – 20 cm soil layer.

Table 8: Organic Matter (%) and Available N, P And K (mg kg-1) as Affected by Plough Depth and Applied Organic Amendments in Calcareous Soil (2019/2020)

Plough depth	Treatments	Soil depth	OM (%)		N (mg kg^{-1})		P (mg kg^{-1})		K (mg kg^{-1})	
			2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Chisel (20 cm)	Control	0-20 cm	1.17	1.31	24.9	27.14	17.0	18.70	112.73	122.03
	C 1		1.41	1.62	33.3	38.26	27.0	31.88	131.25	148.32
	C 2		1.54	1.75	39.4	44.24	29.0	33.10	138.16	152.25
Subsoiler (40 cm one time)	Control		1.21	1.38	25.2	27.47	18.0	19.79	109.40	118.15
	C 1		1.34	1.54	27.4	30.78	22.0	25.12	125.60	138.26
	C 2		1.50	1.75	29.8	34.26	24.0	28.34	128.70	144.19
Subsoiler (40 cm twice)	Control		1.27	1.50	26.3	31.56	19.0	22.80	115.83	138.99
	C 1		1.54	1.71	28.8	31.68	25.0	28.50	126.87	147.17
	C 2		1.68	1.90	31.3	36.20	26.5	29.33	133.21	149.45
Subsoiler (40 cm one time)	Control	20-40	0.53	0.62	17.9	20.57	14.0	16.53	90.19	101.01
	C 1		0.67	0.75	20.2	22.02	16.0	17.60	94.20	101.85
	C 2		0.74	0.81	22.2	24.42	17.0	19.35	96.53	111.98
Subsoiler (40 cm twice)	Control		0.57	0.65	19.6	22.58	15.0	17.55	92.66	95.44
	C 1		0.80	0.94	21.2	25.44	17.5	21.00	95.15	97.68
	C 2		0.94	1.04	23.3	25.64	18.3	20.86	97.24	112.81

Concerning the effect of plough depth on the available N-P-K, it can be observed that their highest values were attained for soil tilled by Chisel plough compared to subsoiler**.** They can be ordered as follows: Chisel plough (20 cm) > Subsoiler (40 cm twice) > Subsoiler (40 cm one time). The tillage can help to increase the worm population and aerate the soil to hasten the decomposition of OM (Burwell et al., 1968). It was found that the available values of N-P-K were declined with increasing the soil depth perhaps caused by the leaching across the soil profile after the plant roots have absorbed their nutritional needs.

On another hand, utilizing the subsoiler (40 cm twice) showed higher values of available N-P-K than the subsoiler (40 cm one time). It can be resulted from the tillage practices that increase the aggregates susceptibility to formation so that they can chelated the nutrients released from decomposing the applied organic materials.

3.4 Effect of The Tillage Treatments and The Applied Compost on The Yield (kg ha^{-1}) and Some Yield Components of The Wheat and Faba Bean Crops

Increasing the compost application rate has increased the yield (kg ha^{-1}) significantly for both the wheat and faba bean crops as indicated by the Table 9 for the two seasons (2019/2020) and (2020/2021). Increasing the plowing depth has also increased the yield significantly for the wheat but non-significantly for the faba bean. The most significant relative increase in the wheat yield was by 54.5% and 74.8% for the compost rates C1 and C2 respectively combined with the plowing two times at 40 cm depth compared to the corresponding control. The increment of the wheat grain as affected by the plough depth can be arranged in the descending order: Subsoiler (40 cm twice) > Subsoiler (40 cm one time) > Chisel (20 cm). These results are in agreement with (Achara and Sharma, 1994).

The most significant relative increase in the faba bean yield was by 145.5% for the compost rate C2 combined with the plowing at 20 cm depth then by 86.4% for the compost rate C1 combined with the plowing at 40 cm depth one time. The insignificant increment of faba bean seed yield as affected by plough depth can be arranged in the descending order: Subsoiler (40 cm twice) > Chisel (20 cm) > Subsoiler (40 cm one time) **.**

The interactive effect of the tillage and compost application were complementary to each other as being significant interaction for the wheat yield. On the other hand, the effect of the tillage or compost application on the faba bean yield was independent from each other because their interaction was non-significant. These results may be due to the nature of the roots distribution of the wheat and faba bean along with the enhanced OM% content and macronutrients availability. Additionally, the improved chemical and physical properties of the calcareous soil at the root zoon distrution that enhanced the plant growth and development. The use of the subsoiler for the depth of 40 cm twice and applied compost C2 helped to break up the impervious soil layer, which enhances the water movement into the soil, increases the stored water for longer periods for the plant roots. Consequently, the availability of soil macronutrients increases, especially in the top soil layers.

Regarding the estimated yield components presented in Table 10, increasing the compost rate has increased the wheat and faba bean yield components significantly. The effect of the tillage treatments was significant only for the weight of plant (g) and Spike length (cm) of wheat as well as for the 100 seed wt (g) of faba bean. For the wheat, the compost rate C2 combined with the plowing two times at 40 cm depth showed a significant relative increase by 5.7, 17.2, 5.5, 14.7, and 23.9% for the 100 grains wt. (g), wt. of plant (g), plant length (cm), spike no., and spike length (cm), respectively, compared to the corresponding control. For the faba bean, same treatment showed a significant relative increase by 6.4, 18.5, 112.1, and 84.7% for the 100 seeds wt (g), plant length (cm), no. branches/plant, and no. pods/plant, respectively, compared to the corresponding control. These increments may be due to the increase in the OM% content and increased macronutrients availability with improved hydraulic conductivity. Additionally, the improvement of the calcareous soil physical properties at the top layers such as the structure status attributed to breaking up the impervious soil layer by subsoiler. However, the effects of the tillage and compost treatments on the yield components were independent from each other as their interaction was non-significant except for the weight of plant of wheat.

Table 9: Yield of Wheat and Faba Bean Grown in Calcareous Soil as Affected by Plough Depth and Organic Materials Addition for The Two Seasons

Plough depth	Treatments	Wheat Grain Yield (kg ha^{-1})		Faba bean Seed Yield (kg ha^{-1})	
		(2019/2020)	(2020/2021)	(2019/2020)	(2020/2021)
Chisel (20 cm)	Control	4000.0	4120.0	3352.6	3453.2
	C 1	5817.2	5991.7	5705.4	5876.6
	C 2	6463.6	6657.5	8230.2	8477.0
Subsoiler (40cm one time)	Control	4022.5	4143.1	3423.2	3525.9
	C 1	5876.4	6052.6	6382.4	6573.9
	C 2	6648.3	6847.8	7214.2	7430.6
Subsoiler (40cm twice)	Control	3993.2	4113.0	4577.3	4714.6
	C 1	6170.6	6355.8	6765.4	6968.3
	C 2	6980.3	7189.6	9479.6	9764.0
Tillage $L.S.D_{0.05}$		**88.04**	**90.68**	**1823.42**	**1878.09**
Compost $L.S.D_{0.05}$		**61.71**	**63.57**	**1301.48**	**1340.53**
Tillage		**	**	n.s	n.s
Compost		***	***	***	***
Tillage * Compost		***	***	n.s	n.s

Table 10: Some Yield Components of The Wheat and Faba Bean Plants Under the Effect of The Studied Factors

Plough depth	Treatments	Wheat plants					Faba bean plants			
		100 grain wt (g)	Wt of plant (g)	Plant length (cm)	Spike no.	Spike length (cm)	100 seed wt (g)	Plant length (cm)	No. branches/ plant	No. pods/plant
Chisel (20 cm)	Control	3.90	61.3	93.7	70.7	10.0	92.36	100.83	3.3	13.3
	C 1	4.24	92.0	99.7	78.3	11.7	97.27	111.20	5.0	15.7
	C 2	4.46	169.0	108.7	85.3	13.0	99.99	117.50	7.0	21.0
Subsoiler (40 cm one time)	Control	4.23	129.3	100.7	67.3	10.0	99.56	104.0	3.3	10.0
	C 1	4.46	151.3	105.0	75.0	11.7	103.89	112.7	5.3	14.0
	C 2	4.71	176.7	105.0	79.0	14.0	107.87	118.0	7.0	23.7
Subsoiler (40 cm twice)	Control	4.42	193.7	103.0	78.7	11.3	103.27	96.0	3.3	13.7
	C 1	4.61	211.3	107.0	82.7	12.0	107.73	109.7	5.3	15.7
	C 2	4.67	227.0	108.7	90.3	14.0	109.92	113.8	7.0	25.3
Tillage $L.S.D_{0.05}$		0.43	23.12	5.64	15.368	0.39	3.53	13.18	1.33	6.99
Compost $L.S.D_{0.05}$		0.19	11.44	3.15	3.212	0.69	1.65	3.57	0.64	1.68
Tillage		n.s	***	n.s	n.s	**	**	n.s	n.s	n.s
Compost		**	***	***	***	***	***	***	***	***
Compost* Tillage		n.s	***	n.s	n.s	n.s	n.s	n.s	n.s	n.s

4. Conclusion

Utilizing the subsoiler tillage at the 40 cm depth twice combined with the compost application at the rate C2= 11.9 tons ha^{-1} to the top layers of the calcareous soil can break up the impervious soil layers and improve its physical and chemical properties. Organic matter (OM), structure status and hydraulic conductivity. This enhances the water movement through soil, increases the stored water for longer periods for plant roots, and increases the availability of macronutrients. Consequently, the yield and its components are improved for the wheat and fababean for both studed seasons.

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