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THE EFFECTS OF TILLAGE AND FERTILIZERS ON GROWTH CHARACTERISTICS OF KABULI CHICKPEA UNDER MEDITERRANEAN CONDITIONS

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Mediterranean semi-arid region is sensitive to physical, chemical and biological soil disturbances related to intensive tillage. Presented field experiment was conducted at Razan district, Hamedan, located in central west zone, Iran during the 2017–2018 growing season. It dealt with the effects of different tillage methods and treatments on growth, yield and yield contributing characters of spring Kabuli chickpea (*Cicer arietinum* L.) under irrigated condition. Effects of two tillage methods – inversion tillage (mouldboard ploughing – T1) and non-inversion tillage (chisel ploughing – T2) – in combination with five different fertilization treatments (C: complete fertilizer; 20FYM: 20 $Mg \cdot ha^{-1}$ farmyard manure; 40FYM: 40 $Mg \cdot ha^{-1}$ farmyard manure; NPK: nitrogen, phosphorus, and potassium at 2-1-1 ratio; 0: no fertilizer for the control purposes) were studied. The experiment was carried out in split block design with three replications. Results showed that application of 40FYM under T1 condition significantly decreased the number of days to seedling emergence. The highest number of days to flowering was recorded for plants cultivated with inorganic fertilization and reduced tillage. Application of large amounts of FYM significantly increased the ground cover and canopy width for both tillage methods. The highest number of secondary branches was recorded for combination 40FYM – T1, which was followed by C – T2. The pod number per plant was considerably sensitive to different combination of treatments and the best results were recorded for combinations 40FYM – T2; 20FYM – T2; and 40FYM – T1. A similar trend was also recorded for the total dry matter. The heaviest seeds were observed in cases with the application of high levels of FYM. The highest seed yield was observed for plants cultivated using 40FYM – T2. Furthermore, the highest harvest index was recorded for 40FYM – T2, and C – T2. The results indicate that non-inversion tillage together with high- level FYM application can significantly affect the yield levels.

Keywords: reduced cultivation of chickpea; plant growth; soil organic matter; chemical fertilizer; seed yield

Soil degradation represents one of the most significant issues in terms of maintaining the soil quality and ensuring of food production in the years to come. Soils contain the largest terrestrial carbon pool that is sensitive to climatic changes, as well as changes in utilization of land and agricultural management methods, such as tillage and fertilization (Haddaway et al., 2017). However, various types of human activity can significantly affect the soil organic matter (SOM) pool and thus may decrease the SOM contents and biological activity. If the organisms responsible for decomposition of SOM and binding of soil particles extinct in the soil, soil structure can be easily damaged by rain, wind, etc. This can lead to rainwater runoff and soil erosion, resulting in elimination of potential food for organisms, i.e. the topsoil organic matter (Bot and Benites, 2005).

Soil structure is defined as the manner in which the primary soil particles (sand, silt and clay) are combined and arranged with other solid soil components to form clumps or aggregates; one of the modifiers of soil structure is tillage practice (Shirani et al., 2002). Although soils are tilled principally to reduce weed population, the main aim of soil-manipulating activities lies in stabilization and improvement of crop production. Therefore, selection of the best tillage method, which would be consistent with the conditions, has always been of the greatest interest of agricultural researchers. Although the effects of different tillage intensity have been investigated in some semi-arid Mediterranean regions, its effects have not yet been fully interpreted. This is partly due to the fact that the type of tillage practice and its severity considerably affects other soil properties, such as soil moisture content, the availability of elements, etc. Hence, it is necessary to evaluate tillage methods in terms of different management conditions.

It has been examined that after green revolution, the rate intensity of SOM loss increased considerably. The most important factors affecting this issue include: replacement of mixed vegetation with monoculture of crops and pastures; high harvest index; use of bare fallow; burning of natural vegetation and crop residues; overgrazing; removal of crop residues; drainage and increased amount of fertilizer and pesticide application (Said-Pullicino et al., 2016). Tillage treatments directly or indirectly influence soil hydraulic

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properties, such as water infiltration, etc., which determine the ability of the soil to capture and store water through precipitation or irrigation (Blanco-Canqui et al., 2017; Abbaspour-Gilandeh et al., 2018).

Application of farmyard manure and mulching are considered effective management for semi-arid region and crop cultivation (Kihanda et al., 2007). Organic manure, such as farmyard manure, municipal solid waste, etc., has been utilized as a source of nutrients and organic matter for plants suitable for enhancement of fertility conditions of agricultural lands for a long time (Dao and Cavigelli, 2003). It has been shown that its rational application enhances the water infiltration, water retention, soil water contents, grain yield, and rainfall use efficiency (Cui et al., 2014; Wang et al., 2016). All in all, the improvement in the physical, chemical, and biological properties was achieved by incorporated manures into soils. Multiple studies have shown the beneficial effects of animal manure on soil structural quality, including reduced bulk density, increased porosity, increased water absorption rate, saturated hydraulic conductivity and, etc. (Hati et al., 2006; Fares et al., 2008).

Current tillage methods utilized in semi-arid region of Iran can be divided into two broad groups: inversion tillage and non-inversion tillage. The former is considered a conventional tillage whereby a sequence of operations is applied to make ready a seedling growth zone including complete soil inversion to bury or incorporate crop residues and is usually accompanied by additional mouldboard ploughing (Cooper et al., 2016). The latter is also known as reduced tillage practice (RT), which minimizes the soil disturbance with targeted and appropriate soil disturbance on the basis of specific field needs, meaning that it is necessary to exercise fewer passes in contrast to conventional tillage, but it incorporates the crop residues into the surface (upper 0.1 m) whilst still leaving at least 30% of crop residues on the soil surface (Davies and Finney, 2002). RT methods have the potential to highly improve the soil quality and to reduce soil loss by providing protective crop residues on soil surface, as well as to improve water conservation by decreasing evaporation losses (Morris et al., 2010).

Understanding the changes in plant growth properties under conditions of different tillage methods and fertilizers is important to soil water content and soil nutrient management (Günal et al., 2018). However, lack of data on interactions of soil tillage and fertilizers effects limits the recognition of the efficiency of tillage method on plant growth parameters. Therefore, this information is particularly necessary in the regions with scarce SOM for the purpose of crop production and inappropriate soil conditions are one of the limiting factors for the crop cultivation. Due to the economic and social conditions of semi-arid regions, the use of long-term methods requires the awareness of farmers and their focus on the short-term benefits. The short-term effects of non-inversion tillage along with different fertilizer applications on chickpea performance have scarcely been studied in Iran. The objective of this study was to determine the effects of conventional and RT practices on chickpea yield in a clay loam soil under Mediterranean climate.

Material and methods

This study was conducted at a research farm in Razan, Hamedan province, Iran (latitude 35.39° N, longitude 49.03° E, altitude 1,803 m above sea level) during the 2017–2018 growing season. The location was in the west central part of Iran. The weather is cold and cooler in contrast to other cities in this province. However, summer weather was moderately cool with mean annual temperature 11 °C. The average city annual rainfall was estimated at 350 mm; this mountainous region is generally considered to be moderately cold. According to the Köppen climate classification, location climate is BSk – semi-arid moderate (Peel et al., 2007). The experimental design was a factorial arrangement in the form of randomized complete block design with three replications. Treatments included two tillage methods (T) (T1 is mouldboard ploughing with average depth of 0.3 m plus two repetitions of shallow disk harrowing as inversion tillage method; T2 is chisel ploughing with average depth of 0.15 m plus two repetitions of shallow disk harrowing as non-inversion tillage method) assigned to the main plot. Subplots were treated using five different fertilizers, i.e. C (10% N, 52% P, 10% K, 3.50% S, 0.12% Fe, 0.05% Zn, 0.03% Cu, 0.05% Mn, 0.03% B in recommended dose); 20FYM; 40FYM; NPK (provided from urea, triple superphosphate, potassium sulphate); 0. Six soil samples were prepared from specimens taken at standard depths ranging from 0 to 0.3 m and a composite sample was sent to the laboratory for chemical analysis after mixing. The soil from experimental site was a clay loam soil and it contained 21% sand, 36% silt and 43% clay. The soil showed low organic carbon content (0.41%) with a pH value of 7.54 and total nitrogen and $CaCO_3$ contents of 0.129% and 14%, respectively. Electrical conductivity (EC), as well as iron, manganese, copper, zinc, and potassium contents of the soil were measured at 1.38 $ds \cdot m^{-1}$, 0.79 ppm, 0.61 ppm, 0.41 ppm, 0.43 ppm, and 428 ppm, respectively. Chickpea (*Cicer arietinum* L.) seeds cv. "Arman" were planted on 30 April 2018 and harvested at full maturity stage. Each plot included sixteen rows, 4 m long and spaced at 0.25 m. Seeds were sown 0.05 m apart. Considering the land management, a wheat-chickpea-fallow rotation was applied as a common rotation system in the region. The field, as part of the entire farm, had been managed for 2 years as fallow. Tillage and manure application were performed in February. Planting was carried out one month after manure application. Sprinkler irrigation was applied in 3–7-day intervals. Two seeds were sown per hill and these were thinned to only one seedling per hill after germination. Throughout the entire experiment, pests or diseases did not attack the plants.

Weeds were eliminated by frequent hand weeding. In order to ensure uniform germination, the plot was immediately irrigated after planting. Subsequently, it was irrigated for four times during the growth period. Phenological growth phases were monitored at 1–2-day intervals throughout the season and time to 50% flowering, number of days of vegetative growth period, and number of days to maturity were recorded for each treatment. Canopy width was calculated by measuring the length and breadth of canopy surface for each plant, on the basis of which the mean canopy width was computed and expressed in centimetre, assuming the canopy is rectangular in shape. Plant freshness and weight, biological yield per plant, seed yield, as well as harvest index were measured from a 2.0 m^2 harvest area from the central four rows of each plot when the crop reached the physiological maturity. Analysis of variance procedures with the statistical program SPSS 15.0 and *LSD* test applied for comparison of means were exploited for the purposes of data processing (Janmohammadi et al., 2017).

Results and discussion

The analysis of variance (ANOVA) showed that the two-way interaction effects of tillage × fertilizer were statistically significant for number of days to emergence. Application of T1 and FYM significantly increased the seedling emergence rate. However, plants cultivated with 0 and chemical fertilizers under T2 showed the highest number of days to emergence. Evaluation of other phenological parameters revealed that application of FYM under T1 significantly reduced the number of days to 50% flowering. The highest number of days to flowering was recorded for plants cultivated under T2 with C. To some extent, similar results were observed for the number of days to podding. In relation to both tillage methods, manure application reduced the necessary number of days to podding. However, plants cultivated with FYM started their podding stage much earlier than others. Despite the differences in reproductive stages, these were not significant in terms of the number of days to maturity; only specimens cultivated utilizing C under T1, and without any fertilizer under T1 showed early maturity in contrast to other treatments (Table 1).

Plant height assessment showed that the tallest plants were recorded for specimens cultivated with combinations of NPK – T1, and C – T2. However, no significant difference was observed between other combinations of tillage methods and fertilizers.

Ground cover percentage assessment showed that the highest value was achieved by application of 40FYM under both tillage conditions. Ground coverage by 20FYM and NPK was slightly lower.

Canopy width investigation showed that chemical fertilizer application under T2 was more efficient than under T1. However, the efficiency of FYM application on canopy width was more evident under T1. The highest number of secondary branches under T1 was related to plants cultivated with 40FYM, whereas the highest number of secondary branches under T2 was related to chemical fertilizers application (C and NPK). The first pod height from the ground level was sensitive to different fertilization treatments only under T1. Plants cultivated with 40FYM and C under T1 showed the highest first pod height. As one of the most important traits in determining the yield, the number of pods per plant was strongly influenced by tillage methods and fertilization treatments. The highest pod number per plant was recorded for plants cultivated with 40FYM under T2, which was followed by 20FYM – T2, and 40FYM – T1 (Fig. 1). A similar trend was also observed in

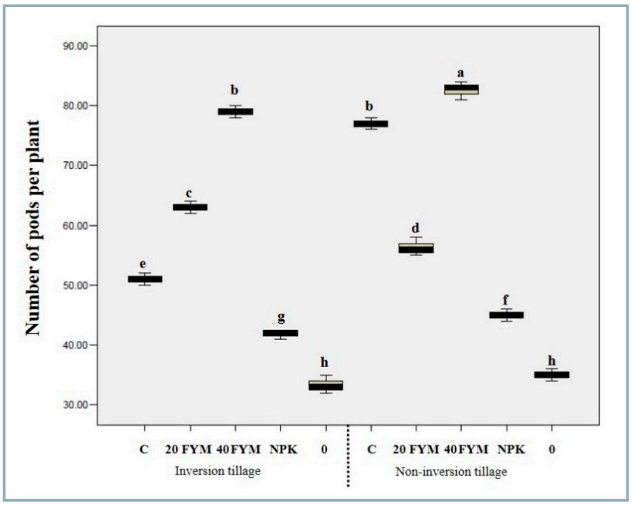

Fig. 1 Effects of different soil fertilizers on the number of pods per plant using different tillage methods; columns with different letters are statistically different at the 5% level

Table 1 Comparison of means of phenological stages and yield components of chickpea (*Cicer arietinum* L.) as affected by fertilizers and tillage methods

	DTE	DTF	DTP	DTM	PH	GC	CW	FPH	STY	HI
T1-C	12.00^{abc}	38.66^{bc}	50.00^{a}	75.66^{d}	27.00^{b}	83.33^{ef}	31.3^{c}	8.66^{a}	226.66^{f}	42.21^{de}
T1-20FYM	9.00^{de}	31.00^{e}	39.66^{e}	83.66^{bc}	30.66^{ab}	96.33^{abc}	43.33^{a}	7.33^{b}	267.00^{d}	43.18^{c}
T1-40FYM	7.33^{e}	29.66^{e}	37.66^{e}	81.00^{cd}	29.66^{ab}	99.33^{a}	44.00^{a}	9.33^{a}	312.00^{a}	44.54^{b}
T1-NPK	12.33^{ab}	39.00^{bc}	49.66^{a}	84.33^{bc}	30.66^{ab}	91.66^{cd}	41.00^{ab}	6.66^{bc}	191.00h	41.68^{fe}
T1-0	12.00^{abc}	38.33^{bc}	49.00^{ab}	80.33^{cd}	28.33^{b}	81.66^{f}g	37.33^{abc}	6.66^{bc}	142.66j	43.00^{c}
T2-C	13.00^{a}	42.00^{a}	50.00^{a}	93.66^{a}	33.00^{a}	94.33^{abcd}	44.00^{a}	6.66^{bc}	290.66^{c}	46.00^{aq}
T2-20FYM	11.00^{bc}	36.66^{cd}	45.00^{cd}	87.00^{b}	28.66^{ab}	92.66^{bcd}	42.00^{ab}	6.33^{c}	262.66^{e}	41.99^{de}
T2-40FYM	10.33^{cd}	34.33^{d}	42.66^{d}	87.00^{b}	26.66^{ab}	98.33^{ab}	40.33^{ab}	6.33^{c}	304.00^{b}	46.49^{a}
T2-NPK	12.66^{ab}	38.66^{bc}	46.66^{bc}	88.66^{ab}	29.33^{ab}	88.33^{de}	45.66^{a}	6.00^{c}	217.33g	51.11^{f}
T1-0	13.33^{a}	4.66^{ab}	49.66^{a}	83.66^{cd}	28.00^{b}	76.66g	33.33^{bc}	5.33^{d}	155.33i	42.53^{cd}

DTE – number of days to emergence, DTF – number of days to flowering, DTP – number of days to podding, DTM – number of days to maturity, PH – plant height, GC – ground cover by canopy, CW – canopy width, FPH – height of the first pod from the ground, STY – straw yield, HI – harvest index. Columns with different letters show statistically significant difference at the 5% level terms of plant dry matter. Plants cultivated with 0 showed the lowest dry matter. Straw yield evaluation showed that application of high level of FYM (40 $Mg \cdot ha^{-1}$) under T1 significantly increased the straw yield. The highest straw yield under T2 was shown by plants cultivated using NPK.

Furthermore, seed size (100 seed weight) was also affected by fertilization treatment. ANOVA showed that the two-way interaction effects of tillage × fertilizer application was statistically significant for this yield component. Plants cultivated with 40FYM under both tillage conditions showed larger seeds (Fig. 2). Considering the seed weight, results showed that the effectiveness of fertilizers under T2 was lower than under T1. Application of C and high levels of FYM significantly increased the number of full pods under both tillage conditions. However, the highest number of semi-filled pods and wrinkled seeds was observed in plants cultivated with NPK and without application of any fertilizer. Seed yield evaluation revealed that the best results were acquired with application of 40FYM and under non-inversion tillage condition. The lowest seed yield was recorded for plants cultivated under inversion tillage without fertilizer application (Fig. 3).

Regarding Fig. 4, the most prominent relations are: a strong positive association between seed yield, 100 seed weight, straw yield, plant dry matter, first pod height, canopy width, pod number per plant as indicated by the steep angles close to zero between their vectors ($r = \cos 0 = +1$).

The cluster analysis of combined treatments based on similarity is shown in Fig. 5. Cluster II showed the lowest performance; it includes 0 under both tillage conditions. Cluster IV includes combined treatments that had the most positive effect on evaluated properties; it contains 40FYM – T2; C – T2; and 40FYM – T1.

Presented findings revealed that phenological development is affected by fertilizers and tillage methods. Plant development is also influenced by the availability of elements and other optimal conditions, such as soil moisture. Results showed that application of NPK and C had the most positive effects on phenological stages. This resulted from high availability and rapid supply of elements via chemical fertilizers for the plant. Moreover, effects of non-inversion tillage were more prominent than those of inversion tillage; this is partly due to the low soil disturbance and high soil moisture content, as well as reduced element leaching. Crop phenology is essential for prediction of physiological responses under varying field conditions. Specifically, in order to avoid confrontation of sensitive developmental stages with adverse seasonal conditions, selection and application of fertilizer and tillage method (changing conditions of the rhizosphere) must be taken into careful consideration in semi-arid regions (Janmohammadi et al., 2014). It is encouraging to compare the obtained results with Sharifi and Namvar (2016), who found that higher nutrient availability and favourable soil conditions can delay crop phenology due to organic source of N.

Furthermore, it was observed that tillage methods and fertilizer application have also impact on canopy height and transverse growth components, such as height and ground cover percentage. Plant growth is controlled by phytohormones ratio. Most stature growth was recorded for plants cultivated utilizing chemical fertilizers under

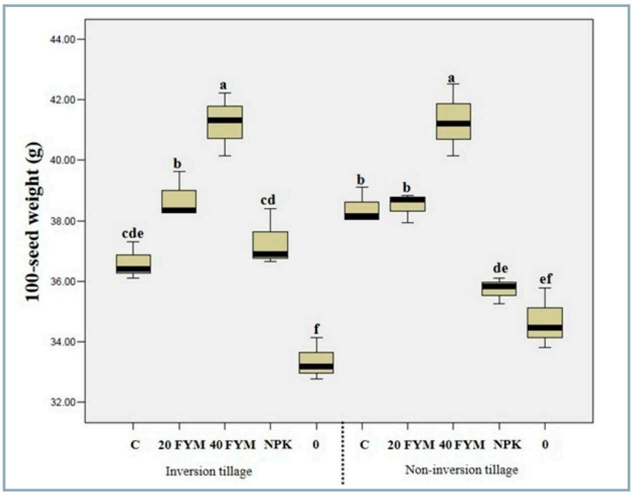

Fig. 2 Effects of different soil fertilization treatment on 100-seed weight under different tillage methods; columns with different letters are statistically different at the 5% level

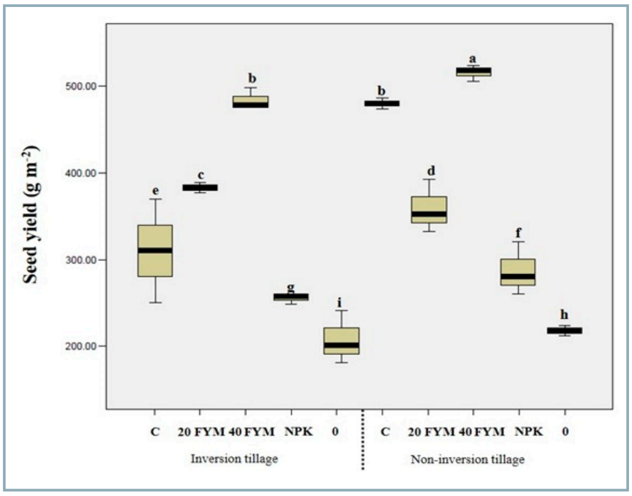

Fig. 3 Effects of different soil fertilization treatment on seed yield under different tillage methods; columns with different letters are statistically different at the 5% level

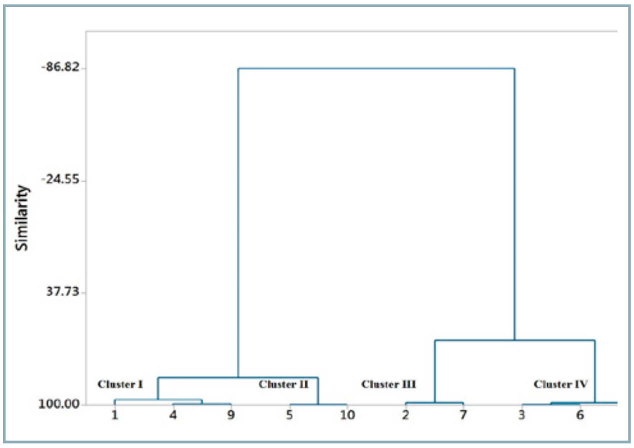

Fig. 4 Cluster analysis of different soil fertilization and tillage methods

1: C – T1; 2: 20FYM – T1; 3: 40FYM – T1; F4: NPK – T1; F5: 0 – T1; 6: C – T2; 2: 20FYM – T2; 3 – 40FYM – T2; F4: NPK – T2; F5: 0 – T2

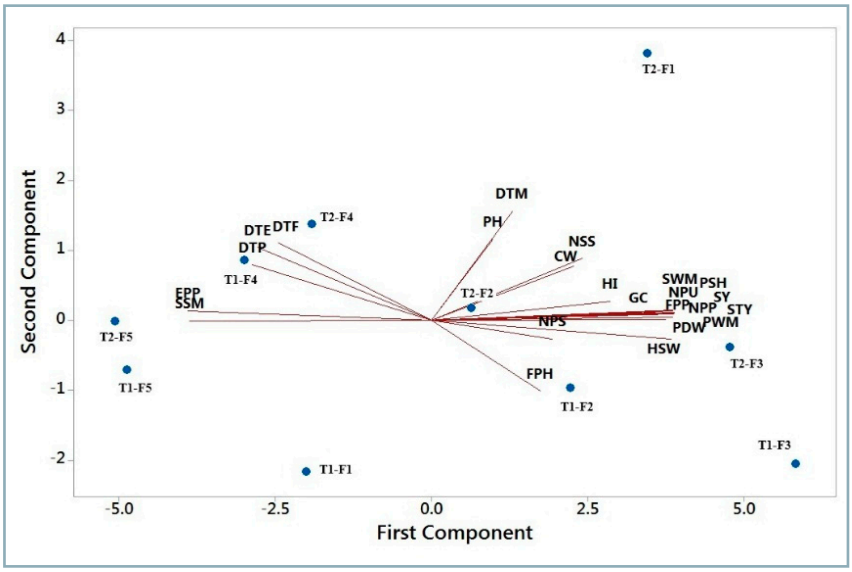

Fig. 5 PCA biplot: spatial distribution of different morpho-physiological traits of chickpea under different soil fertilization and tillage methods using the first two PCs; traits with smaller angles have a significant positive correlation
DTE – number of days to emergence, DTF – number of days to flowering, DTP – number of days to podding, DTM – number of days to maturity, PH – plant height, GC – ground cover by canopy, CW – canopy width, NPS – number of primary branches per plant, NSS – number of secondary branches per plant, FPH – the first pod height from the ground, NPP – number of pod per plant, NPU – pod number per m^2, PDW – plant dry matter per m^2, PWM – pod weight per m^2, SY – seed weight per m^2, STY – straw yield, PSH – pod shell weight, HSW – 100-seed weight, EPP – percentage of empty pods, HI – harvest index)

non-inversion tillage. Increase in plant height due to higher N concentration can be attributed to better vegetative development that resulted in increased mutual shading and intermodal extension. The results indicate that the application of chemical fertilizers has a more pronounced effect than FYM application due to rapid release of the elements in short term. Differences in impacts of tillage methods in question were not significant in this case. In addition to this, results suggest that the non-inversion tillage without application of FYM was not able to create a stable structure and there was not any positive effect on the physical soil properties. On the other hand, it seems that the soil deformation due to wetting and drying, rain and disintegration of soil aggregates was more prominent in cases when inorganic fertilizers were applied.

The results showed that the highest seed yield was acquired by application of high level of FYM under non-inversion tillage. Seed yield is affected by environmental, nutritional and soil conditions and this is more prominent in semi-arid region, where soil and moisture conditions are not so favourable.

Soil quality is affected by multiple external factors, such as utilization of land, soil and crop management, environmental interactions, human objectives, and various natural conditions. Soil organic matter (SOM) is a major indicator of soil quality and health and is strongly influenced by agricultural and fertilization managements. SOM is a major soil source of S, P, N, C; their mobilization, availability and accessibility are continuously changing due to microbial immobilization and mineralization. Furthermore, it improves soil physical properties, water conservation and nutrient availability, ultimately leading to higher biomass content and seed yield. However, the most important factor in semi-arid regions, such as the studied site, is that reduced tillage methods cannot be effective without application of large amounts of FYM. Considering the low rainfall in the studied area and minor return of plant residues to soil, the frequent use of FYM or its combined use with chemical fertilizers can improve performance via optimization of conditions. These results are consistent with Hati et al. (2006) and Naab et al. (2017) and suggest that manure application and reduced tillage improve the plant growth and seed yield in semi-arid regions by improving the soil properties, such as enhanced aggregation root proliferation, increased saturated hydraulic conductivity, reduced mechanical resistance and bulk density.

Selection of the most economical tillage method depends on a number of factors and varies from farm to farm (Epplin and Vitale, 2008; Garcia-Franco et al., 2018). However, since soil and management conditions in the area are relatively similar, experimental results can be generalized. Non-inversion tillage has the potential to conserve soil and water by reducing their loss relative to some form of conventional tillage. It can also reduce time and energy use for crop establishment and nonpoint pollution, as well as enhance the storage or retention of SOM and improve the soil quality at the soil surface. The latter is especially important because SOM preservation can improve the soil water storage and reduce the need for irrigation. In terms of economy and energy saving, there was shown a significant positive effect.

Moreover, it seems that fertilizers can significantly affect the crop nutritional quality. There was observed an increase in concentrations of proteins in cereals and pulses; oil in oilseed crops; starch in tubers; and of essential amino acids and vitamins in vegetables. However, excessive fertilizer application, especially N-based fertilizers, can result in undesirable changes, such as increase in nitrate, titratable acidity and acid-to-sugar ratio and decrease in concentrations of vitamin C, soluble sugar, soluble solids, and Mg and Ca in certain crops. Other agronomic measures, such as tillage and crop rotation, organic farming, soil moisture management, crop breeding and genetic engineering, can also have a large impact on food crop quality; however, potential benefits of these measures for improving the crop quality has not yet been fully explored.

Conclusion

The results revealed that the effects of fertilizers on the evaluated traits depend on applied tillage methods.

Experimental research showed that conservation tillage method without application of organic fertilizers does not have any significant effect on plant growth in short term. Due to the unfavourable soil conditions of semi-arid regions, non-inversion tillage alone is not sufficiently efficient and requires high levels of FYM. Enhancement of plant growth values was recorded for non-inversion tillage method with application of 40FYM fertilizer; this combination of tillage method and fertilizer can improve the physical soil properties and structural stability, minimizing the negative consequences of low water or air penetration on the lower soil layers.

Finally, findings showed that if the soil tillage method is changed, it is necessary to select an appropriate and suitable fertilizer management compatible with the tillage method.

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