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Impact of Soil Management Techniques on Ecological Integrity and Sustainable Apple Growing in Kashmir Valley

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Authors' contributions

This work was carried out in collaboration among all authors. Author MUR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BHB and UIW managed the analyses of the study. Authors ZAT and SS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to study the role of soil mechanization on ecological integrity and yield attributes in apple cultivation. In the experiment, soil management techniques were applied on low density apple orchards (Red delicious/ seedling) continuously for four years in the tree rows and the drive allays, and results were obtained at the end of 4th year in 2017. The experiment was constructed under following design: NT) no-tillage with multi –species ground cover moved twice

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during growing season; MT) Reduced tillage with two ploughings a year (20-25 cm deep) one at the sowing time of intercrop (mustard) during November-December and second after harvesting the intercrop during May; and CT) Four ploughings (20-25 cm deep) in a year with no grass or cover crop. Treatment effects were compared using one-way analysis of varience (ANOVA), and to separate means, Tukey multiple comparisons were used. Results claimed that soil nesting bees, which are valuable pollinators and benefit growers in the form of readily available pollination services, were abundantly found in undisturbed soils (NT) and also enhanced fruit yield (fruit set, fruit retention, seed content and fruit weight). Earth worm saturation, soil moisture conservation and organic carbon content were better maintained under this soil management practice. Maximum available soil nitrogen (198.35 kg/ha) and phosphorus (62.63 kg/ha) were also obtained under NT conditions. Moreover, in case of mustard intercropped plots, although the bee abundance was good but fruit yield recorded was low.

Keywords: Earthworms; fruit set; mustard; red delicious; tillage; wild bees.

1. INTRODUCTION

Soil management techniques play an important role in improving soil structure, biodiversity and nutrient richness, aiming for optimal root growth and activity. In tree fruit production, orchard floor management systems are intended to create the best environment for tree growth, allowing for maximum tree performance [1]. A successful orchard floor management system should increase soil fertility and improve soil physical and biological properties and tree nutrition. The stability of a soil for sustaining plant growth and biological activity is a function of physical and chemical properties [2]. However, many farmers perform tillage operations without being aware of the effect of these operations on soil physical properties and crop responses. Compaction caused by the use of heavy machinery, continuous ploughing for many years with reduced use of organic matter and frequent use of chemical fertilizers, presses the soil particles together, thus reducing the pore spaces containing air and water necessary for good plant growth [3].

One of the most important ecosystem services for sustainable crop production is the mutualistic interaction between plants and animals: pollination. Insect pollination is threatened by several environmental and anthropogenic factors, and concern has been raised over a looming potential crisis. The international community has acknowledged the importance of a diversity of insect pollinators to support the increased demand for food brought about by predicted population increases [4].

Lack of adequate pollination can contribute to a great extent towards low productivity of apple orchards. Most of the apple cultivars are not self-fertile or have only limited degree of self-fertility. In the typical orchard, cross-pollination between different cultivars is the norm. Apples are insect-pollinated, predominantly by hive bees (*Apis melifera* L.) and other wild bees [5]. The efficiency of pollen transfer by insects depends on their abundance, the relative attractiveness of the apple flowers to them, there mode of operation and climatic conditions. Although hive bees usually being more efficient pollinators; their efficacy is adversely affected by the unconducive weather conditions during the blooming period than wild bees [6,7]. Also the renting of beehives from apiculturists is not common and most often unavailable during the period, which makes it necessary to shift to any other sustainable technology for better productivity. Thus to weigh the effect of soil mechanization, the study was undertaken with the objective to evaluate the responses of various soil management techniques on ecological integrity and yield attributes in apple cultivation, with the hypothesis that tillage does not affect the yield attributes, soil physic-chemical or biological properties.

2. MATERIALS AND METHODS

The results presented in this paper were obtained in the year 2017, from the field experiments of low density rain fed apple orchards located at the Koil, Pulwama – J&K ($33^{o}53'57"$N and $74^{o}58'07"$E). Three plots, each representing different soil management technique with Red Delicious apple/ seedling as a main cultivar of approximate age of 20 years selected were more or less 500 m apart. In the experiment, the soil management techniques were applied in the tree rows and the drive

Table 1. Preliminary soil records of the plots obtained during Nov. 2013

	Clay content (%)	Humus (%)	pH	OC (%)	Bulk Density (g/cm^3)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
NT	42	3.4	6.9	1.02	1.21	180.7	49.14	260.31
MT	41	3.6	7.2	0.98	1.26	181.3	45.26	262.18
CT	44	3.4	6.9	1.03	1.22	177.18	47.72	260.54

allays, and were constructed under following design: NT) no-tillage with multi –species ground cover moved twice during growing season; MT) Reduced tillage with two ploughings a year (20-25 cm deep) one at the sowing time of mustard (*Brassica nigra*) intercrop during November-December and second after harvesting the intercrop during May; and CT) Four ploughings (20-25 cm deep) through the year with no grass or cover crop. The respective soil management techniques for the plots so applied were ensured continuously for four years and the data was collected during the fourth year. The preliminary soil observations recorded earlier are as given in Table 1, and no bee hives were installed within a radius of 1 km of the experimental plots. Recommended doses of NPK fertilizers during the period were applied to the trees in a 30 cm wide ring around the trunk, located half way between the canopy periphery and the tree trunk.

Soil samples at the depth of 0 – 25 cm (the level at which the physio-chemical properties of soil were most likely altered due to tillage treatments) were obtained near the canopy periphery. Available nitrogen, phosphorus, potassium, organic carbon and pH were determined using Pusa STFR meter kit, make – WS Telematics. Whereas the soil moisture and soil bulk densities were determined using the procedures given by Gardner [8] and Black [9] respectively. Known volumes of soil samples up to desired depth were collected and later dried to a constant weight. The difference in initial and final weight was calculated as moisture content whereas bulk density was calculated as final dry weight per unit volume. Bee abundance was recorded ten times in each plot during the period of anthesis. Catching nets were used to collect the bees for 15-minute intervals within a row of 50m. Also the earthworm abundance was counted in a 1 cubic feet of soil, at ten random places in each plot during the same period. Similarly, ten random samples from each plot near the canopy peripheries within the rows were taken for soil analysis at the end of harvest. The observations, percent fruit set were recorded 20 days after petal fall, and fruit retention percentage and seed content at harvest. Fruit weight was measured using digital balance. To compare the treatment effects, one-way analysis of variance (ANOVA) was performed for the experiment with 10 replications each, except for yield observations, where the replication count was 30 treatment each. Statistical significance was assessed at $P < 0.05$ and Tukey multiple comparisons of means were used to separate means.

3. RESULTS

The results obtained showed significant effect of soil management practices on the observations recorded (Fig. 1). Among the physical characteristics, lowest mean soil bulk density of 1.188 g/cm^3 was observed in NT soils followed by 1.299 g/cm^3 in MT and the highest 1.588 g/cm^3 in CT. The highest mean soil moisture percentage of 66.651 was observed in NT and the least of 47.224 in CT whereas the moisture percentage of MT soil recorded was 60.120. Soil chemical properties were also significantly affected by the tillage intensities. The highest mean pH (7.61) was observed in MT, followed by CT (7.26) and NT (6.68). Maximum organic carbon percentage of 1.156 was observed in NT and the minimum of 0.674 in CT whereas organic carbon recorded in MT was 0.974%. Nitrogen was found significantly high (198.354 kg/ha) in NT soils followed by 168.675 kg/ha and 103.282 kg/ha in MT and CT respectively. Phosphorus and potassium contents were recorded lowest in MT with the mean values of 20.46 kg/ha and 261.412 kg/ha respectively whereas the highest mean phosphorus content was observed in NT (62.632 kg/ha) and potassium in CT (294.43 kg/ha).

Soil tillage intensity also influenced significantly some biological parameters and the yield attributes. Bee abundance (Fig. 2) was found highest (3.7) in MT followed by 2.9 in NT and 0.7 in CT. Moreover, highest mean earthworm saturation (Fig. 3) of 7.4 was observed in NT, the lowest 0.2 in CT and in MT it was 1.9. Fruit seed content, fruit set and retention (Fig. 1) were observed significantly highest in NT with the

values of 7.37, 62.13% and 50.43% respectively. Lowest seed content 3.07 was observed in CT and in MT the seed content recorded was 5.03. Similarly fruit set and retention in CT and MT were 30.73%, 27.40% and 36.47%, 37.60% respectively. Moreover, fruit weight was observed highest 202.5g in NT followed by 188.5g in MT and 180.07g in CT.

4. DISCUSSION

As per the statistical processing of obtained data, soil bulk density had the highest values for conventional tillage (CT) with significant differences, compared to MT and NT. In NT system, values were the lowest. These low values of bulk density for NT may be due to improved stability of soil aggregates with little disturbance in the soil porosity, as the soil physical properties are found to be more favourable in un-tilled soils. This has also got reflected in the enhanced moisture retention capacity of 29% in NT soils over CT with improved conductivity owing to the continuity of pores. Moreover, under NT soils, the natural grass cover insulating the soil surface, may be the reason for moderating the soil temperature and conserving moisture. McVay et al. [10], also found higher water holding capacity or moisture content in the topsoil (0-10 cm) under no-tillage conditions than after ploughing.

Tillage techniques are often shown to have effect on soil pH [11]. The near to neutral range of pH as observed in NT could be due to buffering action of the electrolytes released by the accumulated organic matter in the upper surface. During et al. [12], observed that with annual no-tillage, plant residues left on the soil surface increase the organic matter in the topsoil. Moreover, the enhanced OC content in the NT soils observed could be due to the conservation of the carbon in the soil aggregates vis-à-vis the accumulation of organic matter. Jacobs et al. [13] have also confirmed the increased concentrations of soil organic carbon and nitrogen within the aggregates under minimum tillage.

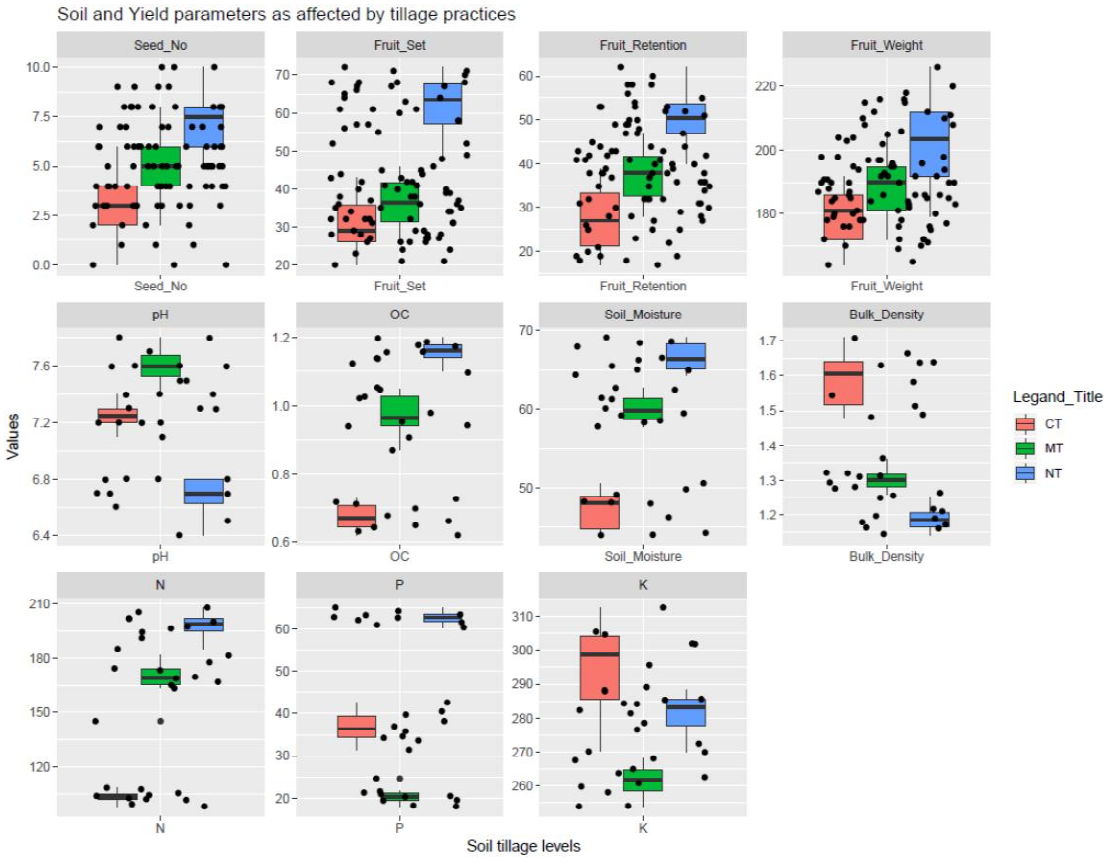

Fig. 1. Soil and yield parameters as affected by soil management practices

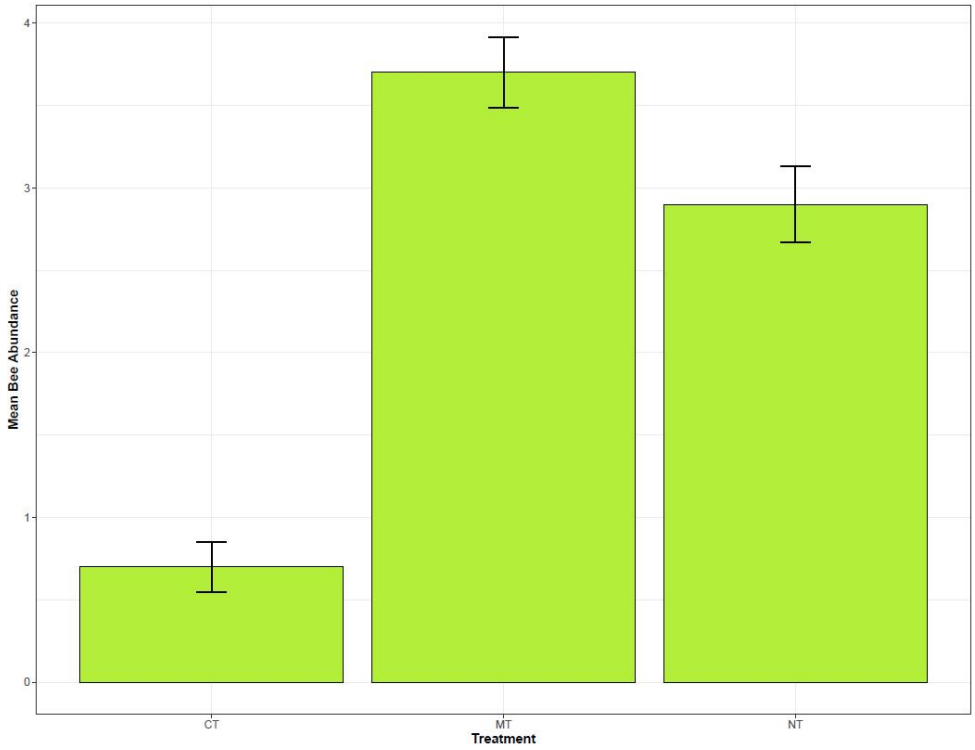

Fig. 2. Bee abundance as affected by soil management practices

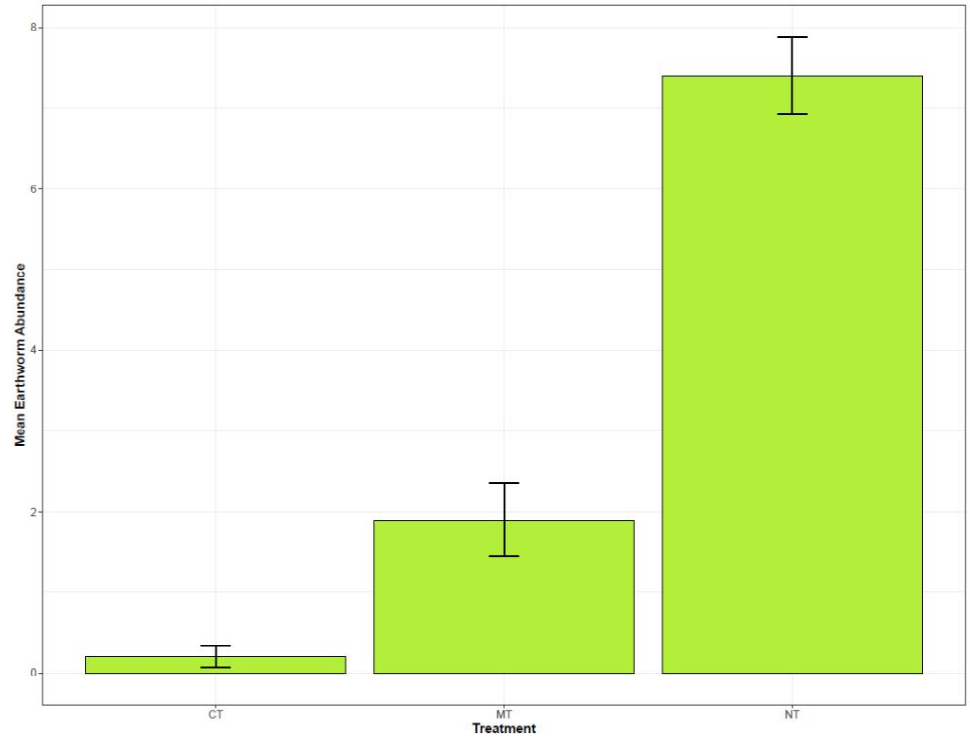

Fig. 3. Earthworm abundance as affected by soil management practices

High content of available N and P as observed in NT soils could be due to reduction of losses due to leaching and their enhanced availability under stabilized soil pH whereas the lowest P and K in MT soils could be due to enhanced uptake by the mustard intercrop. A reduced total N loss was also observed under NT compared to CT by Dala [14]. Higher mineralization and/or leaching rate could be implicated for reduction in organic carbon and total N under tilled plot due to soil structure deterioration following tillage. Little but significant enhancement in K in CT as compared to NT, may be due to the enhanced mineralization of exposed organic materials due to ploughing; as ploughing is known to accelerate mineralization rate of organic materials by exposing the organic matter to microbial decomposition [15,16].

A self-sustaining bee population was found to be highest in MT followed by NT. The bee population counted consisted more of non-honey bee soil nesting species rather than honey bees. The key to large number of soil nesting bees are long-term undisturbed nest sites and dependable food sources. Mathewson [17], demonstrated that a large population of squash bees (soil nesting) got decimated when their nest sites were ploughed. Even minor nest disturbances can be serious, Southeastern blueberry bees have been known to abandon their nests if leaf litter at the entrance is moved [18]. Ullmann et al. [19], have reported a mean change of -53% on the emergence and survival of soil nesting bee offsprings due to tillage compared to control. Though the undisturbed nesting sites were found more in NT soils, but the population count was recorded highest in MT, which may be due to more attraction towards flowering in intercropped mustard. Low seed count evident in apple fruits in highly populated MT plots also approve the statement that bees were more influenced by mustard inflorescence.

Earthworms which are a major component of the soil macrofauna are important in soil fertility dynamics as their burrowing activities aid in improvement of soil aeration and water infiltration. The highest earthworm count thus obtained under NT could be due to the undisturbed, ameliorated soil environment rich in organic matter. Andersen [20] revealed a significantly higher earthworm population under no-till soil than under ploughed soil. Also Kemper et al. [21] reported that less intense tillage increased the activities of surface-feeding earthworms.

For adequate fruit set, pollination is a prerequisite especially in case of apple. Apple pollen being relatively large and not getting carried away by winds, may be the reason for low fruit set in CT apple where bee activity was also found to be meager. Moreover, pollen germination and pollen tube growth are key events in the sexual reproduction of plants [22]. Seeds are usually formed, and the ovary and receptacle enlarge if pollination and fertilization occur normally in apples. This could be the reason behind the comparatively high seed content in NT followed by MT. it would be worth mentioning here that the pollinating agents were found higher in MT as compared to NT, but lower seed content in MT apples could be due to distraction of pollinating agents towards mustard intercrop as discussed earlier.

Simultaneously, seeds produce indole-3-acetic acid, gibberellins and cytokinins during growth. These plant growth regulators apparently control fruit growth, which was evident in NT apples with high fruit weight corresponding to high seed number. Currently, it is accepted that both fruit set and fruit development are regulated by the coordinated action of hormones produced in the ovary after pollination or fertilization [23]. Pollination and subsequent fertilization lead to a strong shift in the balance of phytohormones and development of the ovule [24]. Fruit retention was also found maximum in NT corresponding to their highest fruit seed content. Gibberellins either from fruit seed or exogenously applied, have been found to intensify organ ability to function as nutrient sink and also can increase the biosynthesis of IAA in plant tissue which delays the formation of the separation layer and thus enhances fruit retention. Reports claim a correlative relationship of depleted endogenous levels of gibberellins with mango fruit abscission [25,26].

5. CONCLUSION

This study led to conclude that excessive tillage of low density apple orchards is not helping anyway; whether it is yields, nutrient richness or biological diversity. Ecological imbalance thus created by excessive tillage, adds to the input costs for the benefit of none. To make the ecosystem work and to be less reliant on paid services like, bee hives for pollination, vermicomposting as soil amendment or excessive fertilizers for plant nutrition; yields in low density apple orchards can be enhanced, and the soil properties maintained in a

sustainable way by adapting to no ploughing. Getting to no-tillage will also influence the benefit cost ratio of the orchardist by regulating the input costs in the form of reduced labour costs for soil tillage.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Weibel F. Soil management and in-row weed control in organic apple production. The Compact Fruit Tree. 2002;35:118-121.
2. Mulumba LN, Lal R. Mulching effects on selected soil physical properties. Soil and Tillage Research. 2008;98:106-111.
3. Lampurlanes J, Martinez CC. Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with Barley root growth. Agronomy Journal. 2003;95: 526-536.
4. Annon. The International Treaty on plant genetic resources for Food and Agriculture. FAO. 2008; IT/GB – 3/09/Inf.10.
5. Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham SA, Kremen C, Carvalheiro LG, Harder LD, Afik O, Bartomeus I, Benjamin F, Boreux V, Cariveau D, Chacoff NP, Dudenhoffer JH, Freitas BM, Ghazoul J, Greenleaf S, Hipolito J, Holzschuh A, Howlett B, Isaacs R, Javorek SK, Kennedy CM, Krewenka KM Krishnan S, Mandelik Y, Mayfield MM, Motzke I, Munyuli T, Nault BA, Otieno M, Petersen J, Pisanty G, Potts SG, Rader R, Ricketts TH, Rundlof M, Seymour CL, Schuepp C, Szentgyorgyi H, Taki H, Tscharntke T, Vergara CH, Viana BF, Wanger TC, Westphal C, Williams N, Klein AM. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science. 2013;339:1608–1611.
6. Martins KT, Gonzalez A, Lechowicz, MJ. Pollination services are mediated by bee functional diversity and landscape context. Agriculture, Ecosystems and Environment. 2015;200:12-20.
7. Park MG, Joshi NK, Rajotte EG, Biddinger DJ, Losey JE, Danforth BN. Apple grower pollination practices and perceptions of alternative pollinators in New York and Pennsylvania. Renewable Agriculture Food Systems. 2018;1-14.
8. Gardner WH. Water content. In: Black CA, (Ed.). Methods of soil analysis, Vol.1. American Society of Agronomy. Madison. Wisconsin, U.S.A. 1965;83-127.
9. Black CA, (Ed.). Methods of soil analysis, Vol.1. American Society of Agronomy. Madison. Wisconsin, U.S.A. 1965;374-390.
10. McVay KA, Budde JA, Fabrizzi K, Mikha MM, Rice CW, Schlegel AJ. Management effects on soil physical properties in long-term tillage studies in Kansas. Soil Science Society of America Journal. 2006;70:434–438.
11. Rasmussen KJ. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review. Soil and Tillage Research. 1999;53:3–14.
12. During RA, Thorsten H and Stefan G. Depth distribution and bioavailability of pollutants in long-term differently tilled soils. Soil and Tillage Research. 2002;66: 183–195.
13. Jacobs A, Rauber R, Ludwig B. Impact of reduced tillage on carbon and nitrogen storage of two Haplic Luvisols after 40 years. Soil and Tillage Research. 2009; 120:15–24.
14. Dala RC. Long-term trends in total nitrogen of a vertisol subjected in zero tillage, nitrogen application and suitable retention. Australian Journal of Soil Research. 1992; 30:223–231.
15. Grace PR, MacRae IC, Myers RJK. Temporal changes in microbial biomass and N mineralization under simulated field conditions. Soil Biology and Biochemmistry. 1993;25(12):1745-1754.
16. Agele SO, Ewulo BS, Oyewusi IK. Effect of some management systems on soil physical properties, microbial biomass and nutrient distribution under rainfed maize production in a humid rainforest Alfisol. Nutrient Cycling Agroecosyst. 2005;72: 121–134.
17. Mathewson JA. Nest construction and life history of the eastern cucurbit bee, *Peponapis pruinosa* (Hymenoptera: Apoidea). Journal of Kansas Entomological Society. 1968;41:255-261.
18. Cane JH. Nesting biology and mating behavior of the southeastern blueberry bee. Habropoda laboriosa (Hymenoptera

Apoidea). Journal of Kansas Entomological Society. 1994;67:2236-241.
19. Ullmann K, Meisner M, Williums N. Impact of tillage on the crop pollinating, ground-nesting bee, *Peponapis pruinosa* in California. 2016;232:240-246.
20. Anderson EL. Corn root growth and distribution as influenced by tillage and nitrogen fertilization. Agronomy Journal. 1987;79:544-549.
21. Kemper WD, Trout TJ, Segeren A and Bullock M. Worms and water. Journal of Soil and Water Conservation. 1987;42: 401-404.
22. Wu J, Qin Y, Zhao J. Pollen tube growth is affected by exogenous hormones and correlated with hormone changes in styles in *Torenia fournieri* L. Journal of Plant Growth Regulators. 2008;55:137-148.
23. Mariotti L, Picciarelli P, Lombardi L, Ceccarelli N. Fruit set and early fruit growth in tomato are associated with increases in indoleacetic acid, cytokinin, and bioactive gibberellin contents. Journal of Plant Growth Regulators. 2011;30:405-415.
24. Obroucheva N. Hormonal regulation during plant fruit development. Russian Journal of Developmental Biology. 2014;45:11-21.
25. Bains KS, Bajwa GS, Singh Z. Abscission of mango fruitlets. I. In relation to endogenous concentrations of IAA, GA and ABA in pedicels and fruitlets. Fruits. 1997;52:159-165.
26. Singh Z, Malik AU, Davenport TL. Fruit drop in Mango. In: Horticultural Reviews, vol. 31, by Janick J. (Ed.). John Wiley and Sons Inc., Oxford, UK. 2010;111-153.

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