The Pharma Innovation Journal 2022; SP-11(7): 849-854

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 849-854

www.thepharmajournal.com
Received: 22-04-2022
Accepted: 24-05-2022

Sneh Yadav
Department of Forestry,
CCSHAU, Hisar, Haryana, India

KS Ahlawat
Department of Forestry,
CCSHAU, Hisar, Haryana, India

Chhavi Sirohi
Department of Forestry,
CCSHAU, Hisar, Haryana, India

Todar Mal
Department of Agronomy,
CCSHAU, Hisar, Haryana, India

KK Bhardwaj
Department of Soil Science,
CCSHAU, Hisar, Haryana, India

Corresponding Author
Sneh Yadav
Department of Forestry,
CCSHAU, Hisar, Haryana, India

Soil moisture conservation pattern in poplar based agroforestry system in semi-arid region

Sneh Yadav, KS Ahlawat, Chhavi Sirohi, Todar Mal and KK Bhardwaj

Abstract
The present study was undertaken to assess the soil moisture content under 3x3 m spacing of poplar at 1 m and 1.5 m away from tree line as compared to control (sole wheat crop) at different depths (0-15, 15-30 and 30-45 cm) when wheat crop was grown as an intercrop with poplar during 2019-20 and 2020-21. Among all the depths of soil, the maximum soil moisture content was found at 30-45 cm soil depth and at a distance of 1.5 m from poplar tree line. The moisture content was higher under 3x3 m poplar intercropping as compared to control (sole wheat) during both the year of study. Maximum per cent increase in the moisture content (30.95, 27.85 and 24.71%) was recorded at a distance of 1.5 m from tree line in soil depths at 0-15, 15-30 and 30-45 cm, respectively after 14 days of 6th irrigation over control (sole wheat) during 2020-21. Moisture content (7.7%) was less in control (sole wheat) as compared to wheat under poplar plantation (8.82%) at a distance of 1 m away from tree line and soil depth of 0-15 cm before 5th irrigation during 2019-20.

Keywords: Moisture content, *Populus deltoides*, wheat, irrigation, agroforestry, tree line

1. Introduction
Agroforestry means the efficient land-use system of cultivating agriculture crops, forest crops and livestock simultaneously or sequentially on the same piece of land without degrading the natural ecosystem and augmenting overall production. It is a wealthy, multi-functional and climatically smart agriculture alternative to control land deterioration and gain ecological balance according to the surroundings (Montes *et al*., 2020) [1]. It refines the peasantry's economic conditions and fortified livelihood security besides conserving the natural resources of soil, water, and biological diversity. However, one of the major issues in arid and semi-arid locations is the competition for water between crops and trees in agroforestry systems (Ong and Kho, 2015) [2]. In accordance with tree phenology and age, this competition varies over time and in all three spatial dimensions (Teixera *et al*., 2003) [3]. Annual crops usually utilize only a small portion of the available rainfall and water reserves in the soil. Unlike herbaceous or annual plants, the root systems of many trees may reach water from deeper soil horizons. Perennial trees can improve the amount of water transpired and boost biomass yield in a farming system (Ong *et al*., 1992; Wallace *et al*., 1995) [4, 5]. This may be accomplished directly by trees taking advantage of rainfall and water reserves outside of cropping seasons, or by a greater percentage of rainfall during a farming season transpiring rather than evaporating, running off, or draining to below the rooting zone (Ong *et al*., 1992) [4]. It may also be achieved indirectly when modification of microclimatic conditions by trees increases the transpiration efficiency of the crop and the production of biomass per unit water transpired (Brenner, 1996) [6]. When trees are introduced to a farming system, overall production will only rise if the positive effects of trees on their shared environment and the additional harvestable items they give overshadow the negative consequences of competition with the crop. The main factor affecting crop yield in semi-arid agroforestry systems is competition for water between trees and crops (Singh *et al*., 1989 [7]; Breman and Kessler, 1995 [8]). During the crop-growing season, when trees and crops compete for water, trees exert the majority of their competitive pressure on soil water. However, in some farming systems where retained moisture is crucial for crop output, water usage by trees prior to crop sowing is a significant factor in yield loss. Crop germination failure can also be severely hampered by the removal of soil water prior to sowing. When the land remains fallow, trees can dry the soil, providing less moisture for crop development and perhaps not enough moisture for seeds to be germinate. By minimizing the unproductive elements of the water balance, such as run-off, soil evaporation, and drainage, agroforestry may increase water usage efficiency (Bayala and Wallace, 2015) [9].

By including trees in land use systems, it may be possible to collect the high percentages of potentially available water that are lost to biological production, while effects on groundwater recharge may also need to be taken into account (Ong *et al*., 2006) [10]. Additionally, many trees in agroforestry systems capture water resources that would not be used productively in the absence of trees, primarily from deep soil layers beyond the reach of annual crops. Crop roots in drier surface soil may benefit from hydraulic lift of moisture by trees from wet soil at depth (Burgess *et al*., 1998) [11], either at night when transpiration is low (Hultine *et al*., 2003) [12] or during the day along water potential gradients driven by variation in soil salinity (Hao *et al*., 2009) [13].

Populus deltoides (*Populus deltoides* Bartr. Ex Marsh.) known as Poplar belongs to the family Salicaceae. It is one of the most important tree for agroforestry due to its fast growth (20-25 m^3/ha/yr), deciduous nature, short rotation period (6-8 years), its easy compatibility with agricultural crops and above all high industrial demand. Poplar has high economic returns, store nutrients in soil and used for carbon sequestration and phytoremediation. It is highly suited for fertile, irrigated and well drained soils of sub-tropical climate (Yadav *et al*., 2022) [14]. Wheat is one of the most important winter crop being grown in association with poplar and considered as most appropriate agroforestry systems of North India. This is because poplar can modify the architecture of its roots to improve complementarity between trees and crops in response to the competition from crop. Poplar's deciduous phenology reduces evapotranspiration, which contributes considerably to its low water impact on water use rather improves water productivity with a dormancy phase that coincides with the peak development of winter crops (Zomer *et al*., 2007) [15]. Keeping in view the ever increasing demand of poplar wood and the interest of farmers in poplar culture, the present study was conducted to evaluate the soil moisture content under 3x3 m spacing of poplar in comparison to control (sole wheat) in semi-arid region of Haryana.

2. Materials and Methods

The present study was carried out during 2019-20 and 2020-21 in already established 2.8 and 3.8 years old poplar plantation (planted in February, 2017), at 3×3m spacing at research area of Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana located at 29° 10' N latitude and 75° 43' E longitude at an elevation of 215 m above mean sea-level in the semi-arid environment of North-Western India. The study site is located in subtropical-monsoonic climate zone, which receives an average annual rainfall of 350-400 mm, 70-80 per cent of it received during July to September. While during summer, maximum temperature ranges from 40 to 45 °C in the month of May-June, whereas in December and January temperature (ranges from 0 to 20 °C) falls down up to 0 °C. The soil of the experimental site is sandy-loam type and medium in organic carbon, available nitrogen, phosphorus and potassium. During the experimental period, the mean monthly values of weather parameters such as relative humidity, temperature, evaporation and rainfall were recorded at the meteorological observatory CCSHAU, Hisar, which is one kilometer distance from the experimental site which is presented in Figure 1 (a&b).

2.1 Soil moisture studies

Wheat crop was raised in the interspaces of poplar trees planted at a spacing of 3x3 m and also in control (devoid of trees) during the *Rabi* season of 2019- 20 and 2020-21. The soil moisture content (per cent on dry weight basis) was determined by gravimetric method by drawing soil samples before, after 7 and 14 days of each irrigation applied to the wheat crop. Where treatment represents B1I (Before 1st irrigation), A7D1I (After 7 days of 1st irrigation), A14D1I (After 14 days of 1st irrigation), B2I (Before 2nd irrigation), A7D2I (After 7 days of 2nd irrigation), A14D2I (After 14 days of 2nd irrigation), B3I (Before 3rd irrigation), A7D3I (After 7 days of 3rd irrigation), A14D3I (After 14 days of 3rd irrigation), B4I (Before 4th irrigation), A7D4I (After 7 days of 4th irrigation), A14D4I (After 14 days of 4th irrigation), B5I (Before 5th irrigation), A7D5I (After 7 days of 5th irrigation), A14D5I (After 14 days of 5th irrigation), B6I (Before 6th irrigation), A7D6I (After 7 days of 6th irrigation) and A14D6I (After 14 days of 6th irrigation). The soil samples were drawn at different soil depth viz., 0-15, 15-30 and 30-45 cm with the help of locally fabricated post hole auger at a distance of 1 and 1.5 m away from the tree line under poplar plantation as well as from control (sole wheat). The soil moisture per cent was calculated by drying the soil samples in the oven at 105 °C till a constant weight was attained and the loss in soil moisture was expressed in per cent on dry weight basis. The moisture per cent was worked out as follows:

$$\text{Moisture content (\%)} = \frac{\text{Weight of moist soil (g)} - \text{Weight of oven dry soil (g)}}{\text{Weight of oven dry soil (g)}} \times 100$$

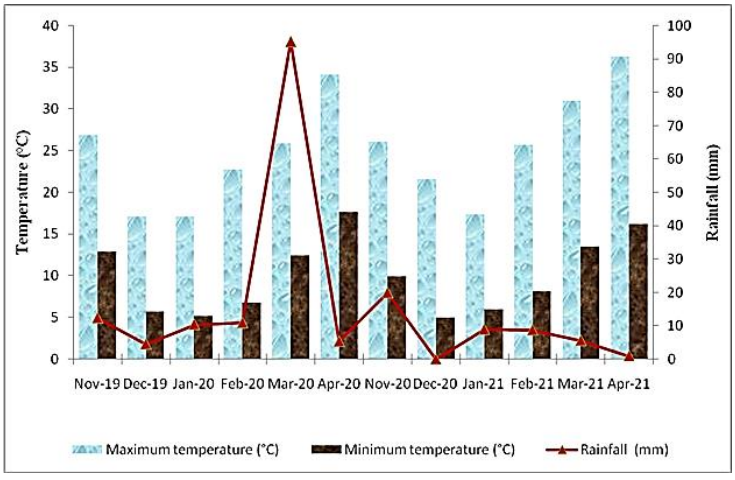

Fig 1: Mean monthly data of meteorological parameters during the study period at the experimental site

3. Results and Discussion

It is evident from the data presented in Figure 2 and Figure 3 that the maximum soil moisture content was recorded under poplar based cropping system (3x3 m spacing) than control (sole wheat crop) at all the soil depths during the whole duration of crop growth. Under 3x3 m spacing of poplar, 10.96%, 20.30% and 23.30% more soil moisture content as compared to control was recorded at a soil depth of 0-15 cm before, after 7 and 14 days of 1st irrigation respectively, at a distance of 1 m from poplar tree line during 2019-20. Similarly during 2020-21, 12.75%, 21.53% and 24.09% more moisture content was observed under 3x3 m spacing of poplar at a depth of 0-15 cm as compared to control before, after 7 and 14 days of 1st irrigation. Similar trend was recorded at all irrigation and at both 1 m and 1.5 m away from tree line during both the years *i.e.* 2019-20 and 2020-21. The differences in moisture content under poplar plantation as compared to control was clearly visible from first to sixth irrigation of wheat during both the years.

The moisture content increased with the increase in the soil depth in under both poplar plantation as well as in control. The perusal of data presented in Figure 2 to Figure 5 show that the maximum moisture content (15.59%) was found at a soil depth of 30-45 cm which was closely followed by 15-30 cm (13.80%) and 0-15 cm (11.98%) before 1st irrigation in 3×3 m spacing of poplar during 2019-20. Moreover, the per cent increase over control in soil moisture content also increased with increasing depth and same trend was observed during all the observations recorded throughout the crop growth period. According to Bosi *et al*., (2020) [16], soil water availability is more dynamic in upper soil layer due to faster water uptake by plants and evaporation from the soil in the first days of a dry spell (Silva *et al.,* 2020) [17]. Due to the strongly concentrated roots in surface strata (Bayala and Prieto, 2020) [18], there was more competition for water in the soil's uppermost layers (Platis *et al*., 2019) [19]. Soil moisture content was also affected by the distance from the tree line. Under poplar plantation, maximum loss in soil moisture content was observed before 3rd irrigation at 1 m distance from tree line. Similar findings were also reported by Kombra *et al.* (2022a) [20] they found that moisture content increased substantially at different distances from tree line (1.5, 2.5 and 3.5 m). Before 1st irrigation, moisture content under poplar based agroforestry system was 11.98% and 12.18% at 1 and 1.5 m distance from the tree line at a depth of 0-15 cm, respectively. Furthermore, In all the irrigations, the per cent increase in soil moisture over control increased continuously as we moved away from the tree line (1 to 1.5 m) at all the depths (0-15, 15-30 and 30-45 cm) upto the midpoint (1.5 m) of poplar spacing. The maximum increase in per cent soil moisture (30.95%) over control was observed at 0-15 cm depth and 1.5 m away from tree line under 3x3 m spacing of poplar after 14 days of 6th irrigation during 2020-21. In contrast, the minimum per cent increase in soil moisture (4.91) over control was observed before 3rd irrigation at a depth of 30-45 cm and distance of 1 m from the tree line during 2020-21. Similarly, Kombra *et al*. (2022b) [21] also concluded that minimum per cent reduction (9.4) in soil moisture was recorded after 7 days of 1st irrigation at a distance of 3.5 m from eucalypts tree line at a soil depth of 30-45 cm when barley crop was grown in the interspaces of eucalypts plantation.

After 7 days of irrigation, higher moisture content was available to crop compared to moisture available before irrigation and again decreased after 14 days of irrigation as compared to moisture available at 7 days after irrigation. It was also observed that after 7 days of each irrigation, the per cent increase in moisture content was found lower in comparison to 14 days after irrigation. However, under poplar, the moisture content was found to be significantly lesser from 1st irrigation to 6th irrigation during both the years of observations. The control plot resulted in less moisture content (7.7%) than under poplar (8.82%) at a distance of 1 m away from tree line and soil depth of 0-15 cm before 6th irrigation during 2019-20. The maximum per cent increase in the moisture content (30.95, 27.85 and 24.71%) in all the soil depths (0-15, 15-30 and 30-45 cm) respectively, was recorded at a distance of 1.5 m from tree line after 14 days of 6th irrigation over control (sole wheat) during 2020-21.

It was based on the fact that there is direct relationship between soil moisture and shade due to tree canopy. Sirohi *et al*. (2022a [22], b [23]) studied that when compared to narrow spacing, intercrop productivity was higher when poplar tree rows were spaced farther apart. They further reported that the soil fertility and soil moisture build up were higher with the close spacing and close to the tree base line as compared to distant from the tree base line. Being a deciduous tree, poplar start shedding its leaves from mid-November. The litter acts as a mulch on the surface layer of soil and reduce the evapotranspiration losses of soil moisture. Zomer *et al*. (2007) [15] reported that the deciduous phenology of poplar minimizes the evapotranspiration, which contributes considerably to its low water impact on water use rather improves water productivity. Furthermore, the dormancy period of poplar also coincides with the peak growth of winter crops and absorbs a lesser amount of water from the soil, resulting in more water availability for the intercrops. Sirohi *et al*. (2019) [24] had reported similar results. They found that the soil moisture content was higher under various spacings of poplar in the poplar-wheat based cropping system as compared to the control (sole wheat). Also Burgess *et al*. (1996) [25] reported poplar and wheat crop don't compete much for soil moisture. According to Bayala and Wallace (2015) [9], agroforestry could be a potential measure in curtailing the unprofitable aspects of water balance like drainage, soil evaporation and runoff losses. This strategy also improves the water use efficiency by reducing the unproductive components of the water balance. Many tree root systems can access water from deeper soil horizons than herbaceous or annual plants. Positive effects on crops may also arise through improved water relations (Bayala *et al*., 2008) [26] and microclimate (Muthuri *et al*., 2014) [27]. Similar findings were also reported by Sirohi and Bangarwa, (2017) [28] who studied that poplar-based agroforestry system had better available nutrients status and soil moisture in comparison to sole wheat crop.

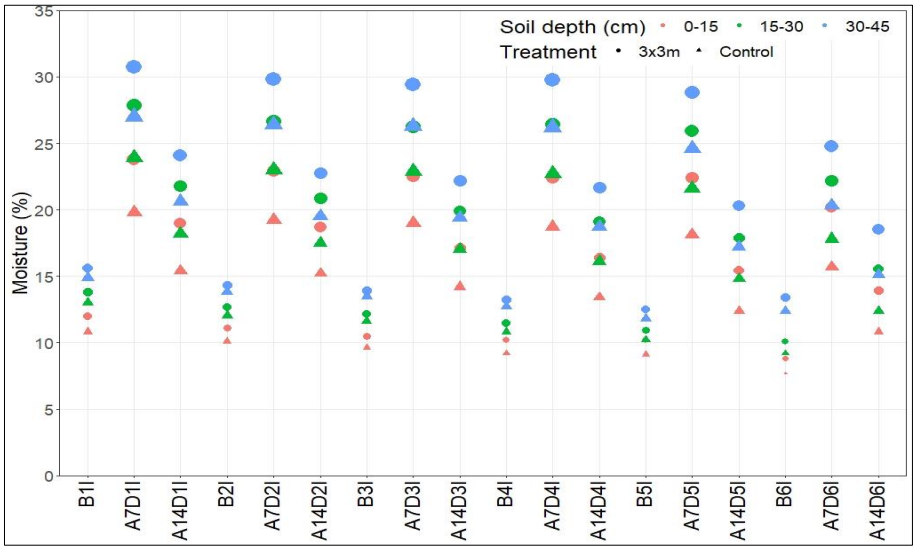

Fig 2: Moisture content (%) before, after 7 days and 14 days of each irrigation at various soil depths at a distances of 1 m from tree line in wheat under 3x3 m spacing of poplar plantation and control during 2019-20

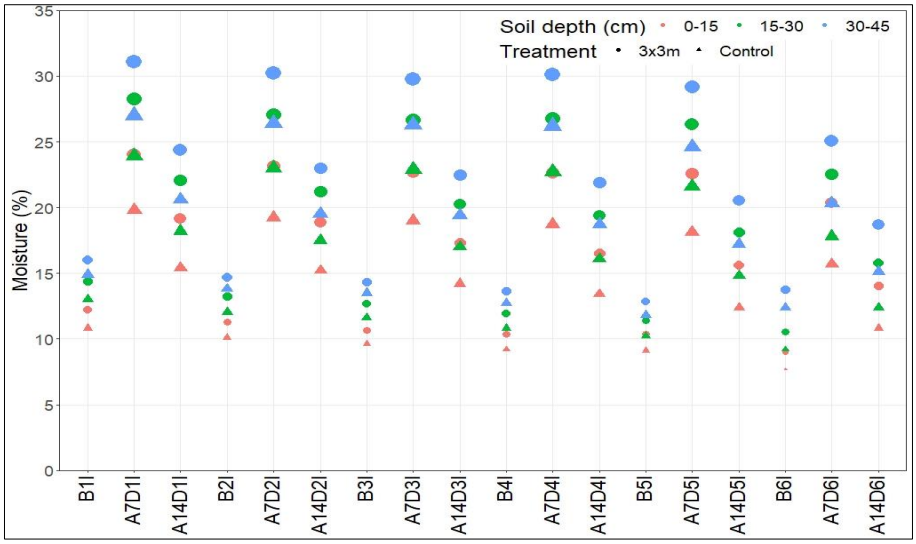

Fig 3: Moisture content (%) before, after 7 days and 14 days of each irrigation at various soil depths at a distance of 1.5 m from tree line in wheat under 3x3 m spacing of poplar plantation and control during 2019-20

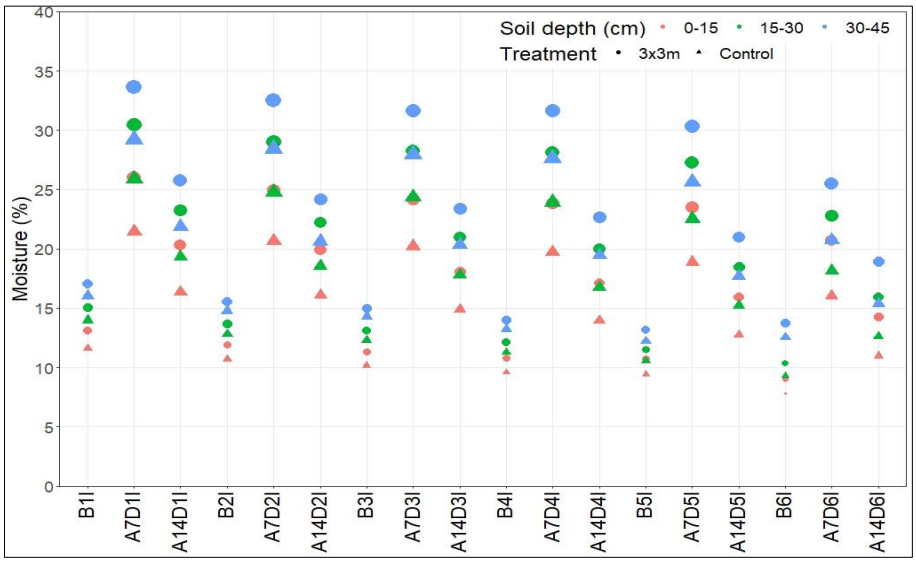

Fig 4: Moisture content (%) before, after 7 days and 14 days of each irrigation at various soil depths at a distance of 1 m from tree line in wheat under 3x3 m spacing of poplar plantation and control during 2020-21

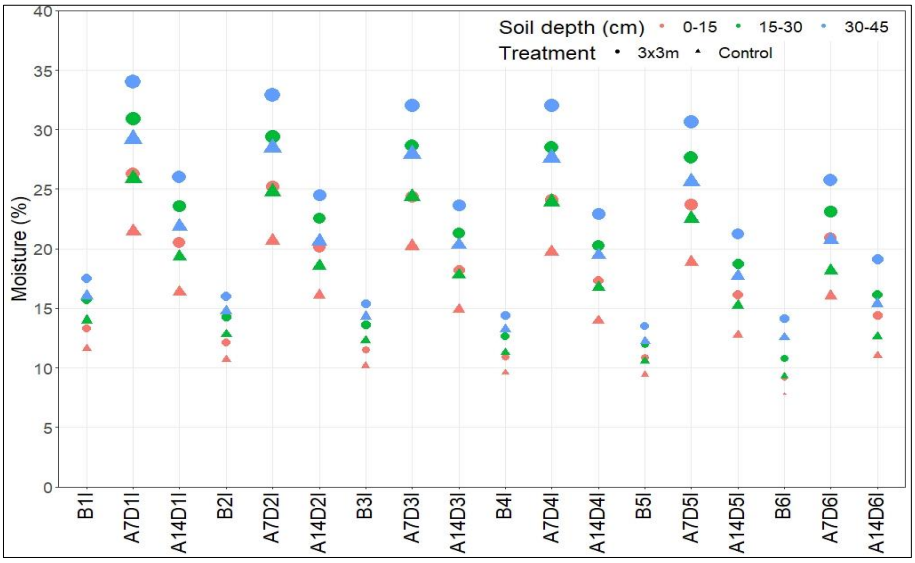

Fig 5: Moisture content (%) before, after 7 days and 14 days of each irrigation at various soil depths at a distance of 1.5 m from tree line in wheat under 3x3 m spacing of poplar plantation and control during 2020-21

4. Conclusion

The present investigation concludes that wheat intercropped with 3x3 m spacing of poplar plantation, found best for optimum soil moisture conservation during both the consecutive years. The maximum increase of 24.46% soil moisture over control was observed at 0-15 cm depth and 1.5 m away from tree line under 3x3 m spacing of poplar after 14 days of 1st irrigation. During this study, the moisture content was lesser in control plot (devoid of poplar tree) as compared to under poplar based cropping system during all the irrigations as well as all the soil depths due to the presence of maximum sunlight which is mainly responsible for low moisture content in semi-arid region of India.

5. Acknowledgment

The authors acknowledge the infrastructure and support of Department of Forestry, CCS Haryana Agricultural University, Hisar without whom this work wouldn't have reached its completion.

6. References

1. Montes O, Uribe M, Castro R, Villanueva C, Pérez M, Lara A. Policy forum: Proposal of a Mexican precision agroforestry policy. Forest Policy and Economics. 2020;119:102292.
2. Ong CK, Kho R. A framework for quantifying the various effects of tree-crop interactions In: Black C, Wilson J and Ong CK (Eds.), Tree-Crop Interactions: Agroforestry in a Changing Climate. CABI, 2015, 1-23.
3. Teixera WG, Sinclair FL, Huwe B, Schroth G. Soil water. In: Schroth G and Sinclair FL (Eds.), Trees, crops, and soil fertility: concepts and research methods. CABI, Wallingford, U.K, 2003, 209-234.
4. Ong CK, Odongo JCW, Marshall F, Black CR. Water use of agroforestry systems in semi-arid India. In growth and water use of forest plantations. Eds. I R Calser, R L Hall and P J Adlard. John Wiley and Sons, Chichester, UK, 1992, 347-358.
5. Wallace JS, Jackson NA, Ong CK. Water balance of agroforestry systems on hill slopes. ODA research Project R4853, Natural Environment Research Council, 1995, 39.
6. Brenner AJ. Microclimate modifications in agroforestry. In Tree Crop Interactions- A physiological approach. Eds. Ong CK and Huxley P. CAB International, Wallingford, UK. Chapter 5, 1996, 159-188.
7. Singh RP, Ong CK, Saharan N. Above- and below-ground interactions in alley-cropping in semi-arid India. Agroforestry Systems. 1989;9:259-274.
8. Breman H, Kessler JJ. Woody plants in agro-ecosystems of semi-arid regions. Springer-Verlag, Berlin, Heidelberg, Germany, 1995.
9. Bayala J, Wallace JW. The water balance of mixed tree crop systems In. In: Black C, Wilson J and Ong CK (Eds.), Trees-Crop Interactions: Agroforestry in a changing climate. CABI, 2015, 140-190.
10. Ong CK, Black CR, Muthuri CW. Modifying forestry and agroforestry to increase water productivity in the semi-arid tropics. CAB Rev. Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. 2006;65:1-19.
11. Burgess SSO, Adams MA, Turner NC, Ong CK. The redistribution of soil water by tree root systems. Oecologia. 1998;115:306-311.
12. Hultine KR, Williams DG, Burgess SSO, Keefer TO. Contrasting patterns of hydraulic redistribution in three desert phreatophytes. Oecologia. 2003;135(2):167-175.
13. Hao XM, Chen YN, Li WH. Indicating appropriate groundwater tables for desert river-bank forest at the Tarim River, Xinjiang, China. Environmental Monitoring Assessment. 2009;152(1-4):67-177.
14. Yadav S, Dhillon RS, Ahlawat KS, Sirohi C, Johar V. Agroforestry: Viable alternatives for ensuring green fodder production around the year. Environment Conservation Journal. 2022;23(1-2):203-210.
15. Zomer RJ, Bossio DA, Trabucco A, Yuanjie L, Gupta DC, Singh VP. Trees and water: Small holder agroforestry on irrigated lands in Northern India. IWMI Research Report No.122. Colombo, International Water Management Institute, 2007, 47.
16. Bosi C, Pezzopane JRM, Sentelhas PC. Soil water availability in a full sun pasture and in a silvopastoral system with Eucalyptus. Agroforestry Systems. 2020;94(2):429-440.
17. Silva VE, Nogueira TAR, Abreu-Junior CH, He Z, Buzetti S, Laclau JP, *et al*. Influences of edaphoclimatic

conditions on deep rooting and soil water availability in Brazilian Eucalyptus plantations. Forest Ecology and Management. 2020;455:117673.
18. Bayala J, Prieto I. Water acquisition, sharing and redistribution by roots: applications to agroforestry systems. Plant and Soil. 2020;453(1):17-28.
19. Platis DP, Anagnostopoulos CD, Tsaboula AD, Menexes GC, Kalburtji KL, Mamolos AP. Energy analysis, and carbon and water footprint for environmentally friendly farming practices in agroecosystems and agroforestry. Sustainability. 2019;11(6):1664.
20. Kombra S, Ahlawat KS, Sirohi C, Poonia P, Singh C, Yadav C, *et al*. Soil moisture status in eucalypts based agroforestry system in semi-arid region of Haryana. Biological Forum: An International Journal. 2022a;14(1):1526-1529.
21. Kombra S, Ahlawat KS, Sirohi C, Poonia P, Singh C, Yadav S, *et al*. Soil moisture status in eucalypts based agroforestry system in semi-arid region of Haryana. Forage Research. 2022b;47(4):494-498.
22. Sirohi C, Bangarwa KS, Dhillon RS, Chavan SB, Handa AK. Productivity of wheat (*Triticum aestivum* L.) and soil fertility with poplar (*Populus deltoides*) agroforestry system in the semi-arid ecosystem of Haryana, India. Current Science. 2022a;122(9):1072-1080.
23. Sirohi C, Dhillon RS, Chavan SB, Handa AK, Balyan P, Bhardwaj KK, *et al*. Development of poplar based alley crop system for fodder production and soil improvements in semi-arid tropics. Agroforestry Systems. 2022b;96:731-745.
24. Sirohi C, Bangarwa KS, Dhillon RS, Chavan SB. Role of poplar (*Populus deltoides*) based agroforestry system for soil moisture conservation in semi-arid region of Haryana. Journal of Pharmacognosy and Phytochemistry. 2019;8(3):1189-1192.
25. Burgess PJ, Stephen W, Anderson, Durston GJ. Water use by a poplar wheat agroforestry system. Vegetation management in forestry, amenity and conservation areas: managing for multiple objectives, University of York, UK. Aspects of Applied Biology. 1996;441:29-136.
26. Bayala J, Van Noordwijk M, Lusiana B, Nimatul K, Teklehaimanot Z, Ouedraogo SJ. Separating the trees oil crop interactions in agroforestry parkland systems in Saponé (Burkina Faso) using WaNuLCAS. In: Jose S and Gordon AM (Eds.), towards agroforestry design- An ecological approach. Advances in Agroforestry, 2008, 285-297.
27. Muthuri C, Bayala J, Iiyama M, Ong C. Trees and microclimate. In: De Leeuw J, Njenga M, Wagner Band Iiyama M (Eds.), Tree salience: An assessment of the resilience provided by trees in the drylands of eastern Africa. World Agroforestry Centre, Nairobi, Kenya, 2014, 81-85.
28. Sirohi C, Bangarwa KS. Effect of different spacings of poplar-based agroforestry system on soil chemical properties and nutrient status in Haryana, India. Current Science. 2017;113:1403-1407.