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Effect of Tree Canopy, Topographic Aspect and Tillage Practices on Growth and Yield of *Ocimum basilicum* in Mid Hills of Indian Himalaya

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Abstract: *The introduction of Ocimum basilicum under Pinus roxburghii forest has been studied to assess the growth and yield for its commercial exploitation and conservation. It was grown below tree canopy and outside tree canopy on three topographical aspects viz. Northern, North-Western, and Western, followed by three tillage depths viz. minimum (0 cm), medium (up to 10 cm) and deep tillage (up to 15 cm) at 30 cm x 30 cm spacing. The growth and yield of Ocimum basilicum were significantly higher outside tree canopy than under storey of Chirpine forests. In other case, the maximum yield was observed on Northern aspect in deep tillage. Thus introduction of Basil (Ocimum basilicum) under Chir pine for developing Chir pine and Basil based silvi-medicinal system without adding any fertilizer and irrigation application and its consequent conservation, which is apparent by its regeneration can be suggested, which will help in utilizing an unutilized part of land and increasing total productivity of forest lands. This practice is also likely to reduce the fire hazards because such kind of activity will not allow the flammable needles to accumulate in bulk in the under storey.*

Keywords: *Basil, Chir Pine, Canopy, Aspect, Tillage*

1. INTRODUCTION

Sweet basil (*Ocimum basilicum* L.) is a small perennial, culinary herb, tropically growing shrub of Asian origin (Dhar, 2002), widely used in systems of indigenous medicine (Paton 1996). It belongs to the genus Ocimum (Lamiaceae), which contains up to 150 species of herb and shrubs in the tropical regions of Asia, Africa, and Central and South America (Simon *et al*., 1990). *Ocimum basilicum* is a globally important economic crop producing annually 100 tonnes of essential oil worldwide and with a trade value as a pot herb of around US $ 15 million per year. Basil has also shown antioxidant and antimicrobial properties due to its phenolic and aromatic compounds (Gutierrez *et al.*, 2008; Hussain *et al.*, 2008). The essential oil of sweet basil possesses antifungal, insect repellent and anti-toxic (Werner *et al*., 1995) and antiviral (Chiang *et al.*, 2005) properties. The leaves and flowers of sweet basil are traditionally used as antispasmodic, aromatic, carminative, digestive, galactogogue, stomachic, and tonic agents (Phippen and Simon, 1998).The essential oil extracted via steam distillation from the leaves and other parts of the plants of basil is used to flavor foods, snuff, dental and oral products, and a fragrance in traditional rituals and medicines (Chang *et al*., 2009; Kirbaslar, 2001). It is widely cultivated for the production of essential oils, and also marketed as an herb, either fresh, dried, or frozen (Putievsky and Galambosi *et al.*, 1999).Usually the plant is regenerated through seeds and creeping stem nodes. But due to the indiscriminate collection of huge amount of this plant by local habitant and Ayurvedic and Unani companies, it is on the verge of extinction. Under such a situation it is important to develop sustainable techniques to meet up the commercial need and its cultivation, regeneration and conservation of such medicinal herbs under the farms or the forests of the Country (Sanwal *et al*., 2011a, 2013).

Chir pine is widely planted for timber in its native area, being one of the most important trees in forestry in northern Pakistan, India and Nepal can offer a unique situation for the promotion and conservation of suitable medicinal and aromatic plants (Sanwal *et al*, 2015, 2016) as it is the fastest growing among the conifers found in the Himalayas. Also Chir pine is hardy, frugal in its soil requirements and adapted to degraded sites which are deficient in nutrients. Like other pines, it is also subjected to influence of various biotic and a biotic factors (Kumar *et al*. 2013; 2016; Khaki *et al*. 2015). Being a light demanding species, it easily rehabilitates exposed sites where most of broad leaved species rarely succeed. Therefore present experiment was conducted to evaluate the growth, yield of Sweet basil (*Ocimum basilicum*) introduced under Chir pine forest and to assess former regeneration after it's harvesting.

In any agro forestry tree based system, biomass production in under storey is a function of photo synthetically active radiation (PAR) falling on the ground surface. Similarly, under a silvi-medicinal system a decrease in incident light can have a significant effect on the yield of understorey medicinal crop, depending on the nature of the crop. Harrington *et al.* (2003) initiated a research to determine the separate effects of above and belowground competition and needle fall from over storey pines on under storey plant performance and found that depending on species, the effects of needle fall were positive, negative, or negligible. Further results indicated that under storey restoration was most successful when herbaceous species were established within canopy openings (0.1-0.2 ha) which managed to minimize negative effects from above and belowground competition and needle fall. Dagley *et al.* (2002) studied the separate effects of over storey and mid storey vegetation in longleaf pine (*Pinus palustris*) plantations. For several species it was recorded that there was an increase in cover during experimental year 1999 and then decrease in year 2000 in response to accumulation of needlefall. Results indicated that plant responses to light availability were strongly regulated by soil water availability and needle fall. Maestre *et al.* (2004) studied direct (competition for soil resources and allelopathic effects) and indirect (competition with herbaceous under storey) interactions between *Pinus* and *Pistacia* and they found no effect of *Pinus* litter and root exudates on *Pistacia* growth. In the field, *Pistacia* seedlings planted under the canopy of *Pinus* showed higher survival than those planted in open areas with sparse vegetation.

As aspect affects the climate of a site which to an extent dependent on its relation to the sun's course and the prevalent wind in the hill areas affecting the insulation and temperature significantly between two extreme aspects (Rosenberg *et al*.,1983). For example, a southwestern slope is sunnier and drier. Since aspect, through its control on solar radiation, affects microclimate, a change in aspect has been known to result in changes in growth rate, species composition, and site quality across a landscape (Fekedulegn *et. al*, 2012). Thus aspect is very influential in hilly regions and creates large differences in microclimate that can be used as criteria for selecting a particular medicinal and aromatic plants managed under a distinct aspect.

Tillage which is mainly concerned with the physical and nutritive conditions of the soil controls the weed growth remarkably especially under pine stand. The general emphasis is that tillage makes the soil more fertile and therefore, can be used as management factor in pine stand. It is worthwhile to mention here that a kind of minimum tillage concept has already been formulated (Russel and Keen, 1938) realizing the importance of weed control as the central objective, can be used as a sustainable management technological input with respect to the cultivation and conservation of medicinal plants under pine stands of mountainous region as studied by Sanwal *et al.* (2011b, 2014). Thus minimum tillage most nearly fulfills the ideal condition for most field crops avoiding compaction of soil without deteriorating the soil structure in hilly area. The minimum tillage depth for growing medicinal and aromatic plants can be used as a sustainable management technology as an agro forestry intervention, applicable to the pine forests of higher elevation across the world, conserving the water and optimum growth factors while utilizing the understorey of the forest. Kothari *et al* (2003) in a field experiment during 1991-2001 under semiarid tropical conditions of Hyderabad studied the effect of tillage depths (15-30 cm) and plant population densities (20, 40, 60 and 80 plants per meter square) on root morphology, yield and quality and cultivation economics of *Withania sominfiera*. Preparatory tillage of 30 cm depth in combination with a density of 60 plants per meter square resulted in the highest root yield of 1.2 t ha $^{-1}$ which was 50 % higher than 15 cm tillage depth. Thus this management input of deep tillage can be applied to the medicinal and aromatic crops where official part is generally the

roots like *withania somnifera* etc. Thus minimum tillage depth or shallow ploughing can be more effective in rain fed mountainous region across the world under pine stand where minimum tillage coupled with accumulation of fallen needle results in moisture conservation and low weed infestations.

2. MATERIAL AND METHODS

2.1. Study Area

The investigations were carried out in different aspects at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The experimental site is located at 30° 51' N latitude and 76° 11' E longitude in survey of India Top sheet No. 55 F/1at an elevation of 1250 m above mean sea level. The climate of the area is transition between subtropical to sub-temperate with maximum temperatures recorded upto 37.8°C during summer. The mean annual temperature is 19.8°C. In general May and June are the hottest months whereas December and January are the coldest ones. The annual rainfall ranges between 800-1300 mm of which 75 per cent is received during mid June to mid September. Growth and yield of *Ocimum basilicum* integrated under Chir pine and without Chir pine (Outside tree canopy) on different aspects and under different tillage practices were studied separately. Hence, studies involved three factors i.e. aspects, tillage practices and systems (Crop grown below canopy of Chir pine and in outside tree canopy conditions). Basil was grown on three aspects viz Northern (A_1), North-Western (A_2) and Western (A_3) at a spacing of 30 cm x 30 cm, followed by three tillage depths viz. minimum (T_1: 0 cm), Medium (T_2: up to 10 cm) and deep tillage (T_3 : up to 15 cm). The 18 treatments, including all possible combination of three aspects, three tillage depths and two systems were used for the evaluation of performance of Basil under three replicates in randomized block design.

Fig3. *Growth of Ocimum basilicum in Chir pine forests*

2.2. Growth Attributes of Chir Pine

The status of Chir pine forest available in all three aspects under which the introduction of Basil was taken place in terms of average height, average diameter and average value of crown area has been presented in the following table.

Table1. *Growth attributes of Chirpine (Pinus roxburghii) Stand*

Aspect	Average height (m)	Average diameter (cm)	Crown area (m^2)
Northern aspect	11.23	19.94	2.99
North-western aspect	10.22	18.15	2.87
Western aspect	11.09	19.39	2.98

2.3. Data Collection and Analyses

Experimental field was prepared by removing the pine needles and tillage practices were done just before the onset of monsoon. Plots were prepared as per the treatment details under different tillage practices. The whole experiment was conducted under rainfed conditions entirely dependent on the monsoon rains. Keeping in view the forest site conditions, no irrigation and fertilizer was applied and the selection of Basil as medicinal plant was done on the basis of its minimum input requirement for irrigation and fertilizers. For the transplanting of seedlings nursery was prepared and with the

commencement of monsoon and after getting the sufficient moisture availability in the soil in first fortnight of July, healthy seedlings of Basil were transplanted in the experimental area from nursery. The crop was harvested in the month of December. The observations on growth parameters (height, number of branches per plant and leaf area index) were recorded at vegetative, pre-bloom and harvesting stage. Whereas, the data for the yield and the yield attributes were measured at the time of harvesting. The growth, yield data of Basil generated from the present investigation were analysed statistically using the technique of analysis of variance for factorial randomized design in accordance with the procedure outlined by Gomez and Gomez (1984). After harvesting of Basil, the area was again visually surveyed to find the regeneration of the Bail seedlings in the next consecutive year after the onset of monsoon in the understory of Chir pine.

3. RESULTS

3.1. Effect of Tree Canopy

Plant height (cm) at vegetative stage, pre- bloom stage and harvest stage was recorded more outside tree canopy than below tree canopy and it was significantly affected in later two growth stages (Fig. 1). Number of branches per plant and leaf area index below and outside tree canopy revealed non-significant effect at pre-bloom and harvesting stages. Economic (Q/ha) and oil yield (kg/ha) significantly decreased below tree canopy than outside tree canopy (Fig. 1).

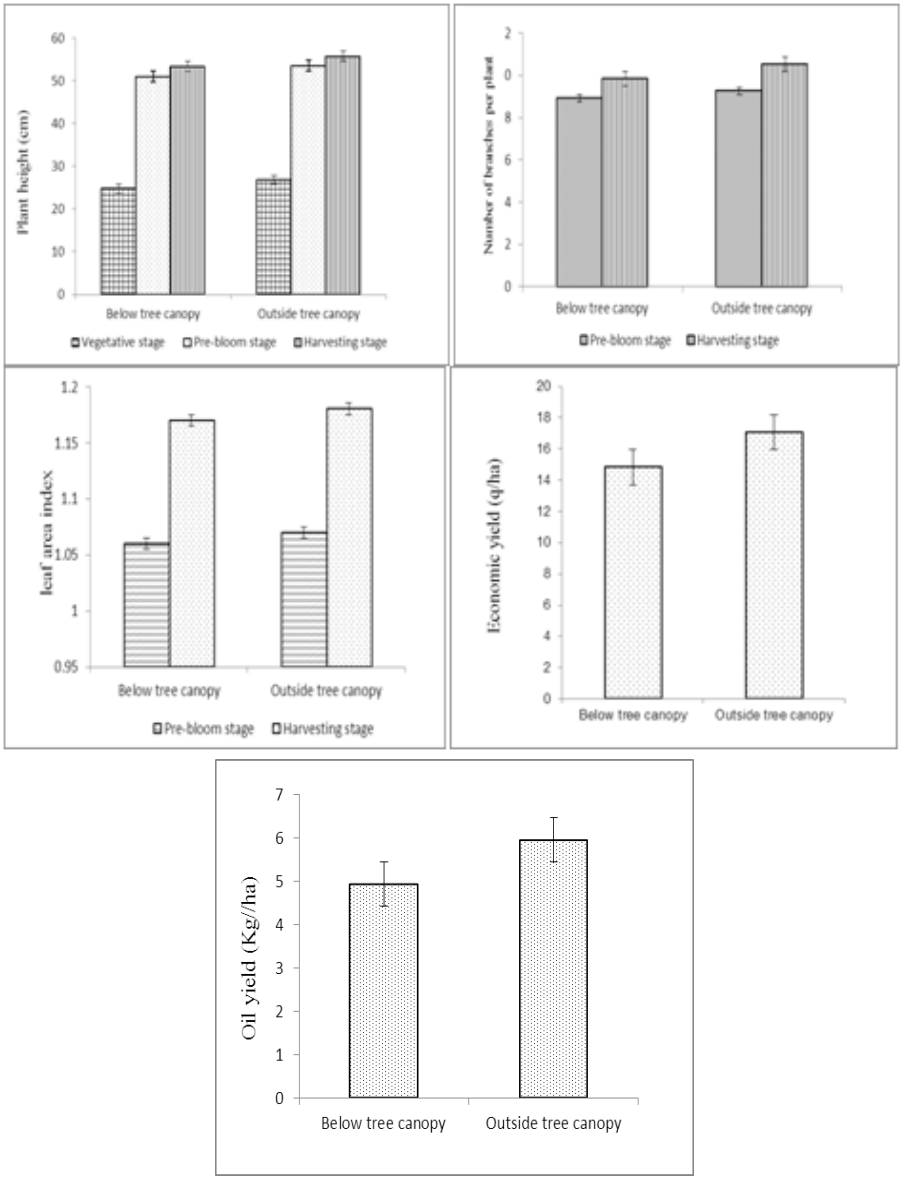

Fig1. *Performance of Ocimum basilicum below tree canopy and outside tree canopy*

3.2. Effect of Aspect

Plant height (cm) at vegetative stage was non significantly differed with changing aspect, but it was significantly affected at pre-bloom and harvest stage (Fig. 2). Number of branch per plant and leaf area index was non significantly affected by aspect at pre-bloom and harvest stage. Economic (q/ha) and oil yield (kg/ha) significantly varied with different aspect and higher yield of these was recorded in Northern aspect than North-western and Western aspect (Fig. 2).

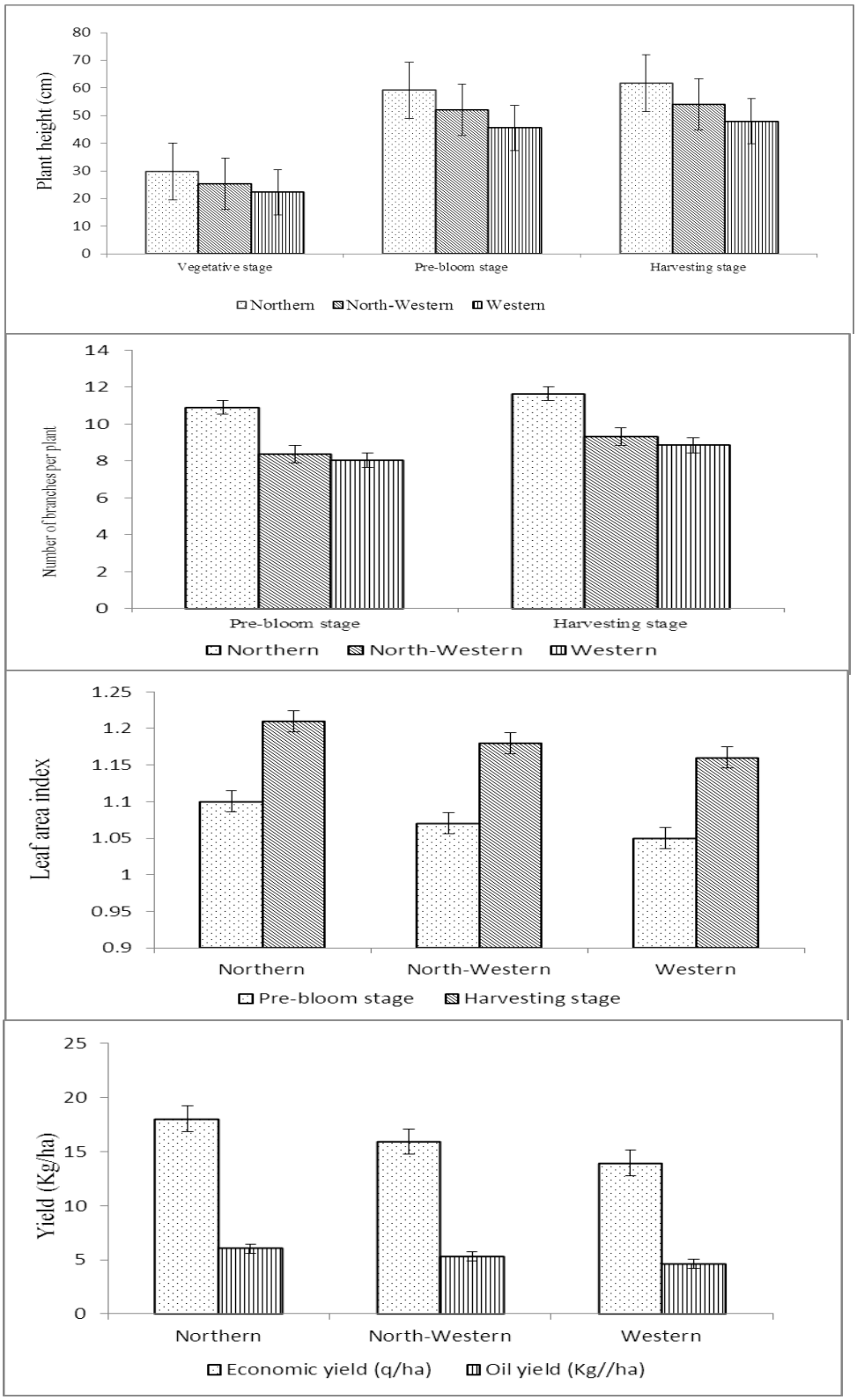

Fig2. *Effect of aspect on performance of Ocimum basilicum at different stages and on yield*

3.3. Effect of Tillage

Tillage non-significantly affected plant height (cm) at vegetative stage, but it was significantly affected at pre-bloom and harvest stage and higher plant height (cm) was observed in deep tillage than medium and minimum tillage at all the growth stages (Table 2). Number of branch per plant and leaf area index varied non significantly with different tillage. Moreover, tillage strongly affected economic (q/ha) and oil yield (kg/ha) and greater yield of both obtained in deep tillage than medium and minimum tillage (Table 3).

Table2. *Effect of tillage on plant height and number of branches per plant at different stages*

Tillage	Leaf area Index		Economic yield (q/ha)	Oil yield (Kg//ha)
	Pre-bloom stage	Harvesting stage		
Minimum	1.04[a]	1.165[a]	9.11[c]	3.04[c]
Medium	1.07[a]	1.18[a]	17.96[b]	5.99[b]
Deep	1.09[a]	1.195[a]	20.78[a]	6.91[a]

Table3. *Effect of tillage on Leaf area index, economic yield and oil yield*

Tillage	Plant height (cm)			Number of branches per plant	
	Vegetative stage	Pre-bloom stage	Harvesting stage	Pre-bloom stage	Harvesting stage
Minimum	21.60[a]	47.38[c]	49.68[c]	6.66[a]	7.99[a]
Medium	26.19[a]	53.13[b]	55.035[b]	9.50[a]	10.40[a]
Deep	29.53[a]	56.30[a]	58.92[a]	11.11[a]	11.90[a]

3.4. Post-Harvest Regeneration of Basil

Having harvested the Basil crop at the end of the growing season, the area was again visually surveyed to find the regeneration of the Basil seedlings in the next consecutive year after the onset of monsoon in the understory of Chir pine. The result was surprising to see the enormous and profuse regeneration of Basil below canopy of Chir pine. The regeneration of the emerging seedling might be due to the mature and dormant seeds sprinkled during the end of the growing season of Basil and on the onset of monsoon and under favorable conditions these lying dormant seeds under the needles of Chir pine might have germinated amid the accumulated pine needles. In this process where there was no distinct regeneration of other species near the profuse emergence of seedlings of Basil, its small size of seeds might have assisted in quick and profuse regeneration of Basil.

4. DISCUSSION

The production potential of Basil can be judged by the effect of different aspect, tillage and systems on growth parameters and final yield.

4.1. Effect of Tree Canopy

Plant growth and yield parameter of Basil was generally higher outside tree canopy than below tree canopy (fig. 1). However the higher values for all growth parameters and yield attributes of Basil outside tree canopy suggests that the plants grown outside tree canopy as sole crop has better opportunities to reap more solar energy for photosynthetic activity, less intra-specific competition for critical resources like water, nutrients, and photo synthetically active radiations. These favorable factors seem to result in higher values of growth and yield parameters in medicinal and aromatic crops in outside tree canopy conditions. Chauhan (2000), Karikalan *et al.* (2002), Singh *et al.* (2012a) and Sanwal *et al.* (2016a, 2016b) have earlier made similar observations for different crops and medicinal plants under agro forestry system. Apart from above the lower values of growth parameters and yield attributes of Basil in below canopy of Chir pine was because of the possibility of accumulation of phytotoxin in soil over number of years, which might led to allelopathic interaction with crops, which cannot be ruled out, since no attempt was made during this study to separate the allelopathic effect of Chir pine. Some of the previous study had shown allelopathic effect of Chir pine on different plants (Singh and Verma, 1988; Gupta *et al.*, 2007;Aliloo, 2012; Sharma, 2013a; Sharma, 2013b). The findings of this investigation are also in agreement with the earlier findings of many researchers (Williams and Gordon, 1995; Singh *et al.*, 2012b) who have reported higher production of dry matter in the outside tree canopy field than in the intercropped field.

4.2. Effect of Aspect

Our result showed the growth and yield parameters observed on Northern aspect was greater than North-West and Western aspect (Fig. 2). Similar result was obtained by Nevo *et al.* (1999). They found that plant cover may reach 150 % on the Northern aspect. Nevo *et al.*(2000) further confirmed that species inhabit on different aspect display genetic, morphologic, physiological and behavioral adaptive complexes in relation to each of the aspect. So the maximum growth and yield of Basil on Northern aspect is attributed to lower intensity of light during forenoon, when the temperature is more favourable and leaves are turgid, resulting in increased rate of photosynthesis. On the other hand, Western aspect receiving higher intensity of light in afternoon, when the temperature is less favourable and leaves are less turgid, limiting photosynthetic efficiency of the crop on this aspect. Nevo (1997) proved that microclimatic conditions on the aspects vary dramatically, affecting the biology of organisms at all levels.

4.3. Effect of Tillage

In our study, plant growth and yield parameter in deep tillage was recorded more than medium and minimum tillage (Table 3 and 4). Higher values of growth and yield in deep tillage were due to better soil permeability, soil aeration, root penetration and weed control. These results are in agreement with the findings of Singh *et al.* (2012b). Similarly observing the effect of ploughing depth, on the development of root system significantly higher yield was found in deep tillage. This was attributed to the favorable effect on plant height, number of branches per plant and shoot and biomass yield. Thus the greater value of growth parameter and yield in deep tillage is attributed to the higher infiltration and increased soil depth for moisture storage (Moreno *et. al*, 1997), while the lower yield under minimum tillage is attributed to less favorable condition for shoot and root growth, and less moisture storage and poor soil aeration. Lampurlanes *et al.* (2002) also reported the reduced shoot growth in compact soil because of the poor root development. The other reason for lower value of growth parameters and yield attributes, are because of poor control on weed growth and less nutrient availability under minimum tillage. Unger and Baumhardt (1999) also reported the reduction in the yield under no tillage as compared to conventional tillage, occurred due to lack of control over the weed population.

5. CONCLUSIONS

Basil showed its potential in below canopy conditions of Chir pine that full fills its requirement of commercial exploitation and conservation. The findings indicate its successful introduction under Chir pine as the profuse regeneration has been observed after its post harvesting during the last growing season. The introduction of Basil can be a viable option, in below canopy of Chir pine which usually remains unutilized to grow any crop, even without adding any fertilizer and irrigation practices, thus such introduction will also prevent competition with food crops for want of land for cultivation. This practice is also likely to reduce the fire hazards because such kind of activity will not allow the flammable needles to accumulate in bulk in the under storey.

AUTHORS' CONTRIBUTIONS

Chandra Shekher Sanwal conducted research work, while Raj Kumar and SnehaDobhal involved in Data analysis and writing manuscript, respectively

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