A Study on Tree-Crop Interactions of Wheat (*Triticum aestivum* L.) and *Eucaluptus tereticornis* planted in Nelder Wheel Design under Shallow Water Table Conditions

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ABSTRACT

Plantation of trees in Nelder wheel design provides varied microclimatic conditions especially in terms of solar radiation penetration for understory crop in agroforestry system. Agricultural production requires very specific soil, water and atmospheric conditions. The area under suitable soil and water condition has already been increased through intensive research, extension and management programmes but the atmospheric conditions on field basis could not be modified easily. Agroforestry may prove to be an effective tool to improve the microclimatic conditions on field basis. The present investigation attempts to study the effect of modified microclimate of wheat as an understory crop grown below 8 year old Eucaluptus tereticornis planted in a Nelder wheel design, planted in fifteen spokes of trees numbered serially starting from north direction as 0^0 *. Wheat cv. PBW-226 was sown on 21st November, 1996 as an under story crop. Studies have been made on the three fluctuating microclimatic conditions created due to orientation of tree rows of the trees at four important phonological stage of the crop i.e. tillering, flag leaf emergence, flowering and maturing stage of the crop along with the control (sole crop).Yield and yield attributing characters were also recorded and compared with control (sole crop). Radiation climate in the three microclimatic zones viz T1 (*312^O*-*72^O*), T2 (*72^O*-*192^O*) and T3 (*192^O*-*312^O*) in the Nelder wheel attributed to the trees row orientation were studied at four important stages of the wheat crop along with control. Correlation coefficients and regression equations between net radiation in control and different treatments below trees were also developed.*

Key words: *Net radiation, Eucaluptus tereticornis, Wheat (Triticum aestivum L.), Shallow water table, Nelder wheel design.*

1. Introduction

The best performance of any cultivar depends upon its genetic potential and favourable environmental conditions to which it has been exposed. To obtain the optimum level of yield in case of wheat (*Triticum aestivum* L.) the daily temperature range should be 20°C maximum, 10°C minimum and 15°C mean daily temperatures. Wheat is grown during the *rabi* (winter) season in north India and this zone constitutes 75% of area under wheat and 82% of production of wheat in India.

The below optimum temperature during vegetative stage and higher than optimum temperature during grain filling stage are major constraints in wheat production in this region.Tree crop integration has many effects on each other. Trees act as wind-break and increase water use efficiency by retarding the water loss by evapotranspiration besides modifying radiation climate, crop energy balance, temperature, photosynthesis and its rate and duration and plant grown for understory crop. Heat load reduction during reproductive phase is found to increase the production of wheat. Introduction of trees in the monoculture can be used to optimize the microclimate in field conditions for winter wheat in North India. Studies are scares so far on tree-crop interactions of Wheat (*Triticum aestivum* L.) and *Eucaluptus tereticornis* planted in Nelder wheel design under shallow water table conditions. The present investigation attempts to quantify the modified microclimate of wheat as an understory crop below *Eucaluptus tereticornis* planted in a Nelder wheel design.

2. Data and Method

The present field investigation was carried out at the Horticultural Research Center, Patharchatta, located in the campus of GB Pant University of Agriculture and Technology, Pantnagar, India (29° N, 79° 30' E, 243.83 m above mean sea level). The climate of the region is humid subtropical, characterized by dry hot summers and cold winters having dry season from early October to mid June and a wet season from mid June to early October. Average annual total rainfall is 1434.4 mm (90% in mid June to end of September). The diurnal maximum air temperatures are highest in May–June and the diurnal minimum air temperatures are lowest in January ranging 3.0 - 41.0°C while relative humidity is highest in July–August and lowest in December–January ranging 35-80%. The experimental area lies as a belt below and a few kilometers south of the foothills of the Himalayan mountains having gently slopped of less than 1% the soils are classified as Mollisols (Deshpande et al., 1971) along with characteristic fluctuating shallow water table ranging from surface to 1.8 m or so below the soil surface. The weather conditions during the experiment is depicted in Fig 1.

Trees of *Eucaluptus tereticornis* planted in a Nelder wheel design in March 1989 (Nelder, J.A. 1962). It consisted of fifteen tree spokes of wheel each oriented at an angle of 24° from the adjacent tree spoke, arranged in ten concentric rings of trees of radii 2.0, 5.4, 13.5, 17.8, 21.5, 24.6, 27.4, 29.9, 32.2 and 34.4 m, respectively, enclosing a total number of 15 plots between the tree rows, numbered serially from 1 to 15 in anticlockwise direction, starting from a tree row oriented to 0° in north direction. Each plot was divided into three sub plots of area 26.62 m^2 for the propose of the investigation. In each spoke the first, second and the tenth trees were considered as buffer trees to avoid border effect. Therefore, a constant tree stand of 333 trees per hectare was provided in the area between the third and the ninth trees of each spoke.

Field was harrowed four times with disc harrow, properly leveled for better germination and growth, before the sowing of experimental crop. Nitrogen, phosphorus and potassium were applied at the rate of 120kg, 80kg, and 60kg per hectare. Half of nitorgen and full doses of phosphorus and potassium were broadcasted during land preparation and mixed thoroughly by cross harrowing. The remaining half dose of nitrogen was top dressed at 25 DAS i.e. just after first irrigation. The wheat variety PBW-226 was sown below the tree canopies with the help of seed drill on 21st. November, 1996. The rate of seed was 100 kg/ha. The seed was sown in rows 23cm apart and at the depth of 5cm. The area not covered by seed drill was sown manually by hand hoe. Two hand weeding were given at 45 and 80 days after sowing. Only one irrigation was given at 20-25 days after sowing at crown root initiation (C.R.I.) stage.

Trees of *Eucalyptus tereticornis* pruned appropriately to provide sufficient solar flecks penetration for growing of wheat as an understory crop. Radiation climate in the three microclimatic zones viz T1 (312^O-72^O), T2 (72^O-192^O) and T3 (192^O-312^O) in the Nelder wheel in each subplot was studied at four important stages of the wheat crop along with control.

For taking observations on growth, yield and yield attributing parameters one meter marked row in each plot was selected at mid of subplot. For yield estimation net plot of 26.62 m^2 of each subplot was harvested and collected into small bundles which were allowed for sun drying in field for 2-3 days, and weighed. Threshing was done net plot-wise with the help of thresher.

Net radiation was measured with the help of portable net radiometers (Middleton Instruments, Australia) and read on portable battery operated micro-voltmeters (Century Instruments, Chandigarh, India). for each treatment at three points in the middle of the area of each subplot of each treatment along with control simultaneously at tillering, flag leaf emergence, flowering stage and maturing stage at half hour interval from morning to evening.

3. Discussion

Data pertaining to the change in tree B. D. H., height and horizontal area has been given from sowing to harvest of the crop in Table1. Average increase in tree height, tree D.B.H. and tree horizontal area were 34 cm, 0.3 cm and 8.07 m^2, respectively.

Plant height at 120 DAS, numbers of tillers was highest in T2 below trees however it was more in control than the understory crop. Though, Flag leaf per meter row length at 80 DAS, ear head emergence at 90DAS, flag leaf length and flag leaf area was more in T2 than all the treatments and also in comparison to control. In general good vegetative growth was observed in T2 followed by T1, T3 and control respectively (Table2). Length of ear head, Sterile/spike and Effective tillers/m were highest in T2 than other treatments below trees and also than that of control. Though, spikelets/ spike, Grain/spike were found highest in control than all other treatments. High temperature during post-anthesis period is found to decrease grain number per spike and 1000 grain weight. The 1000-grain weight (g) was highest in T3 (Table 3). Grain yield and biological yield was almost at par in T2 and T3 (62-64% of control) but was considerably high in control than the understory crop treatments. Harvest index was highest in T3 than other treatments and also than that of control (Table 4). Organic carbon and available N, P and K contents of soil has also found improved in Eucalypts based agroforestry system. Under different aspects of Eucalypts, western aspect in 2m distance have been found more suitable for improving the soil fertility by the addition of leaf litter in a large quantity with the advancement of tree age. Thus, Eucalypts based agroforestry system can sustain the soil health by improving various soil parameters. (Bisht, V. and Bangarwa, K. S., 2015).The yield of wheat and mustard has been reported 2.7 and 5.7 times higher in open field as compared to eucalypts based agro forestry system. Wheat has been found more suitable for cultivation under eucalypts. Lower income under eucalypts could be compensated by income from eucalypts trees at maturity besides other advantages of agro forestry such as supply of fuel, fodder, timber and other ecological services. (Kumar et.al, 2013).

Total diurnal net radiation at tillering, flag leaf emergence, flowering stage and maturing stages of the wheat crop in various treatments is depicted in Fig 2. Diurnal net radiation availability among different treatments and all four stages of crop on half hourly basis under the agroforestry conditions was found highly dynamic on time scale. Net radiation was available more in South direction treatments than that of north direction treatments in Nelder wheel design under tree canopies.

With the advancement of the stage of crop total diurnal net radiation in all the treatments showed increasing trend. At tillering, flag leaf emergence and maturing stage it was nearly at par in T2 and T3. Though, at flowering stage T1 and T2 was almost at par. At all stages of crop growth the total diurnal net radiation was considerably greater in the control than in the understory crop (Fig 4). Total diurnal net radiation at tillering flag leaf emergence, flowering stage and maturing stages ranged 31-55%, 41-50%, 49-63% and 46-61% of control, respectively. Net radiation availability was found more in the south direction treatments than that of north direction treatments under tree canopies. The radiation environment over inter crop was highly dynamic on time scale. This variation in net radiation can also be seen on second basis. The sudden changes in light intensity have considerable effect on photosynthetic responses of crop growing beneath trees.

T2 and T3 had better net radiation availability at all stages of crop growth than T1. The green tree canopy of Eucalyptus might have reduced radiation intensity along with the quality of light in PAR range.

Correlation between net radiation at different stages and yield and yield attributes has been worked out. Correlation between net radiation at different stages and grain/spike, grain yield and biological yield was found significant at 1% and 5% significance level (Table 5). In *tarai* region having shallow water table could provide sufficient subirrigation to wheat crop intercropped with *Eucalyptus tereticornis*. Upward soil water flux contributes 36–73% of the total water requirement of wheat in *tarai* region of foothills, under shallow water table conditions. (Saini and Ghildyal, 1978).

Water table depth did not fluctuate very much during vegetative growth i.e. from November 1996 to mid February, 1997, but, a rapid fluctuation was observed during reproductive phase of crop i.e. from mid February, 1997 to April, 1997. Water table depth in the study area ranged 68-120 cm, respectively during *rabi* season, 1996-97 under tree canopies. The maximum depletion of water table occurred reproductive phase of crop because of high evaporative demand and more water requirement of the wheat crop having no significant effect on the plant water status.

Relationship between net radiation in control and different treatments below trees were developed separately for different stages of the crop. It was observed that there was a significant relationship between the net radiation in control and in understory crop at four important stages of the understory crop (Fig 2 & 3).

4. **Conclusions**

The investigation shows that tree row orientation and their mutual distance has influenced considerably to the vegetative and reproductive phase growth of the crop. However reduced heat load from grain filling to maturity and its elongation in an agroforestry system would have possibly helped to mitigate the effect of shading below trees because excessive solar radiation to sole cropped wheat field at post anthesis period is found to reduce wheat yield.

Deciduous trees such as *Dalbergia sissoo, Trewia nudiflora, Populus deltoides* etc., having defoliation process during vegetative stage of the wheat crop could create good microenvironment along with optimum canopy pruning of tree. Agroforestry can be helpful to improve the microclimatic conditions subjected to the proper tree spacing and their pruning for wheat in an agroforestry system. Further in-depth research is needed to harness the best potential of microclimate modification through agroforestry inder Nelder Wheel design.

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Table 1 Tree D.B.H.(cm), tree height(m) and tree horizontal area(m^2) at the time of sowing and harvest of wheat crop during *rabi* season, 1996-97

Number of ring	Tree D.B.H. (cm) at the time of		Tree Height (m) at the time of		Tree Horizontal Area (m^2) at the time of	
	Sowing	Harvest	Sowing	Harvest	Sowing	Harvest
1.	17.8	18.2	15.48	15.82	51.02	59.99
2.	16.4	16.8	15.24	15.64	43.00	51.27
3.	16.7	17.1	15.70	16.04	46.56	54.36
4.	15.6	15.9	15.02	15.34	39.36	47.53
5.	16.6	16.9	14.99	15.31	40.48	48.27
6.	15.4	15.7	14.02	14.34	38.48	47.29
7.	15.3	15.7	14.00	14.32	33.79	40.48
Mean	**16.3**	**16.6**	**14.92**	**15.26**	**41.81**	**49.88**

Table 2 Effect of different treatments on vegetative growth of wheat as an intercrop under *Eucalyptus tereticornis*

Treatment	**Plant height at 120 DAS(cm)**	**Number of Tillers at 105 DAS**	**Flag leaf/m row length at 80 DAS**	**Earhead emerged at 90 DAS**	**Flag leaf Length (cm)**	**Flagleaf Area (cm^2)**
T1	89.96	79.2	59.06	53.4	30.26	40.84
T2	92.22	99.34	82.28	75.66	32.32	44.64
T3	94.28	95.48	77.32	72.46	31.4	44.02
Control	102.5	105.9	80	68.1	29.4	39

Table 3 Effect of different treatments on yield attributes of wheat as an intercrop under *Eucalyptus tereticornis*

Treatment	**Length of earhead (cm)**	**Spikelets/ spike**	**Grain/spike**	**Sterile/spike**	**1000-grain weight (g)**	**Effective tillers/m**
T1	7.5	13.86	37.2	2.06	43	61.82
T2	8.98	14.68	40.34	2.82	43.08	85.06
T3	8.78	15.4	43.72	2.26	47.8	80
Control	8.2	16.2	46.6	2.2	45.1	82.9

Table 4 Effect of different treatments on grain, biological yield and harvest index of wheat as an intercrop under *Eucalyptus tereticornis*

Treatment	Grain yield (q/ha)	Biological yield (q/ha)	Harvest index
T1	21.94	49.10	0.45
T2	24.56	53.30	0.46
T3	24.11	50.47	0.48
Control	38.51	82.03	0.47

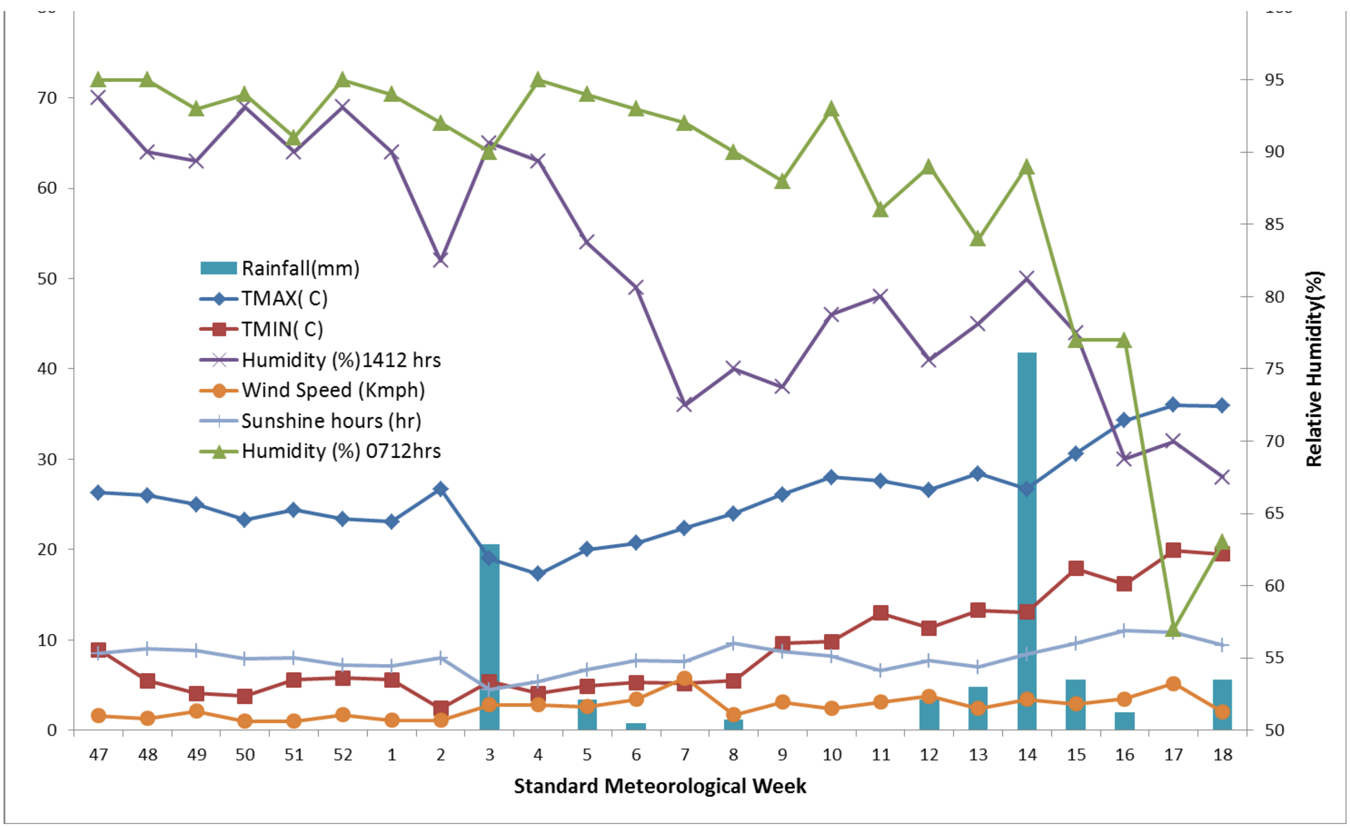

Fig. 1 Weekly average weather data for experimental period (November 1996- April 1997)

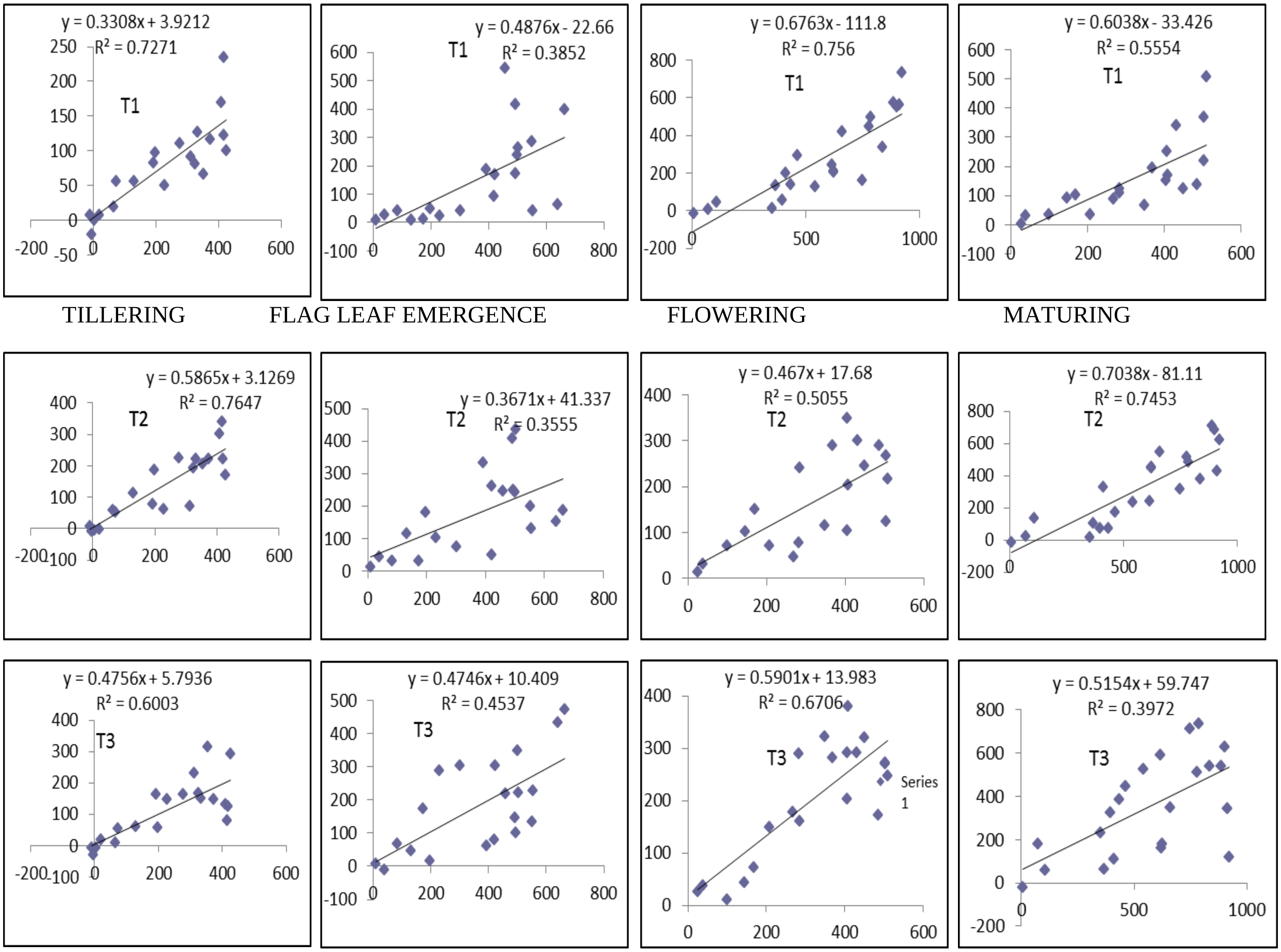

Fig.2 Relationship between net radiation in different treatments and control at different stages of crop growth period

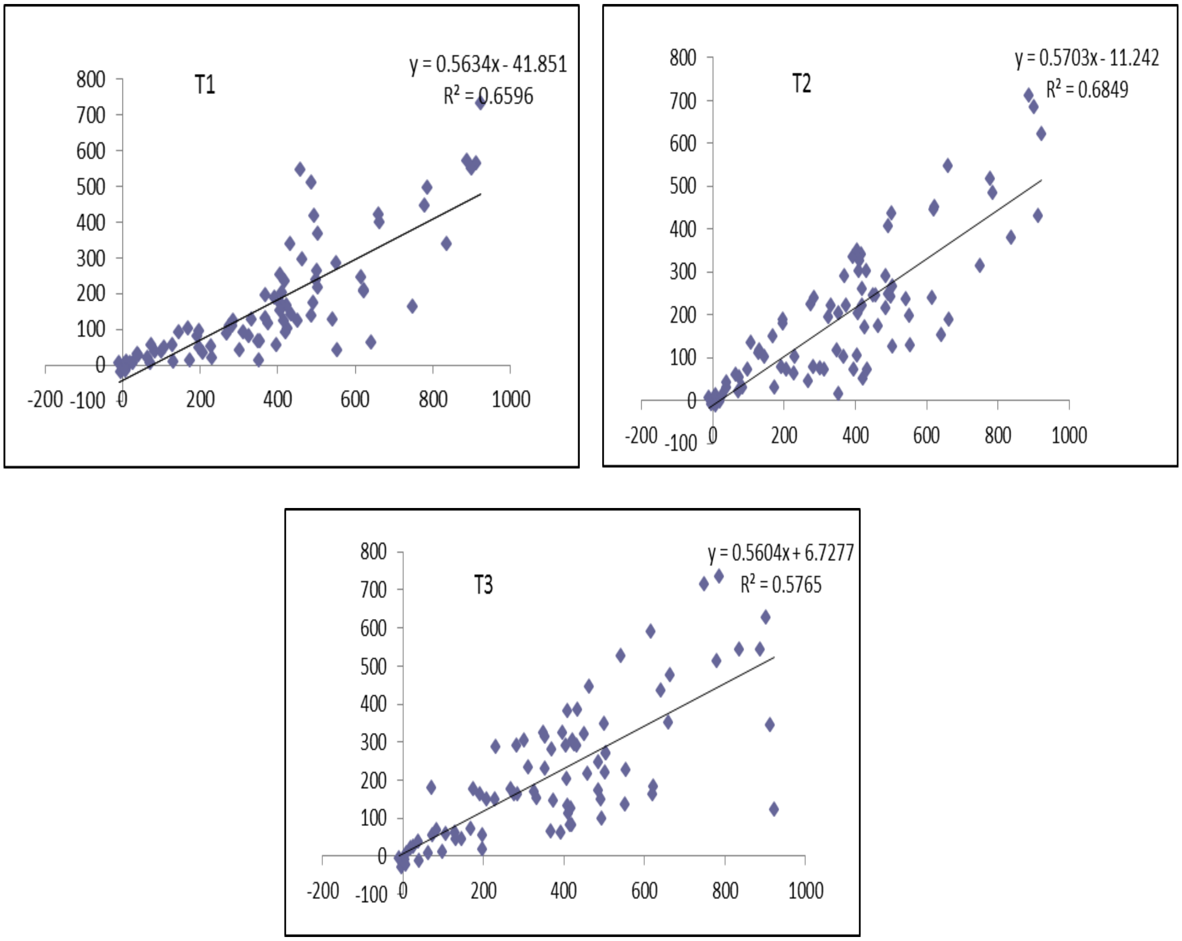

Fig.3 Relationship between net radiation in different treatments and control during crop growth period

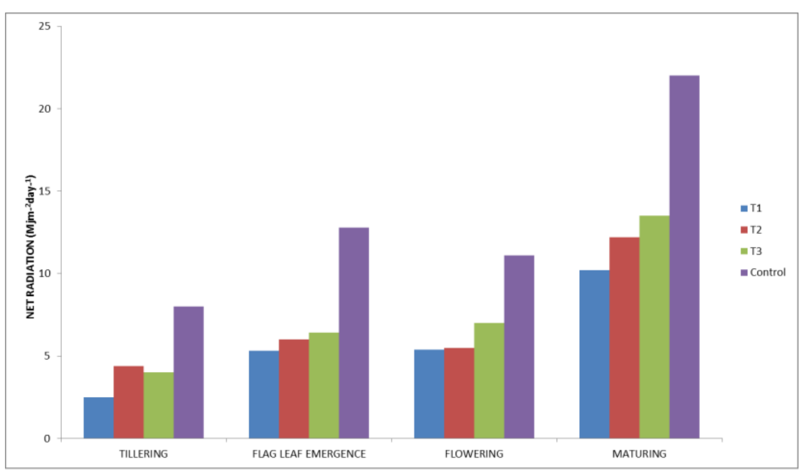

Fig. 4 Total Diurnal Net Radiation at different Stages of the Wheat Crop in various treatments