Indian Journal of Agronomy **66** (1): 33–41 (March 2021)

Research Paper

Tillage and nutrient-management effects on productivity, profitability and resource-use efficiency of wheat (*Triticum aestivum*) in foothills region of Uttarakhand

AMRENDRA KUMAR[1] AND MAHENDRA SINGH PAL[2]

College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

Received: May 2019; Revised accepted: January 2021

ABSTACT

A study was carried out during 2013-14 and 2014-15 at the Norman E. Borlaug Crop Research Centre, Pantnagar, representing the foothills (*Tara*i) region of Uttarakhand, India, to study the effect of tillage and nutrient management on growth productivity, profitability and resource use efficiency of wheat (*Triticum aestivum* L.). The experimental site was silty clay loam having soil *p*H 7.21, organic carbon 0.68% and 242.42, 22.56 and 240.32 kg/ha available N, P_2O_5 and K_2O respectively. The results indicated that the wheat planted on permanent raised bed system (PRBS) and furrow-irrigated raised bud system (FIRBS) had higher plant height, dry matter accumulation, chlorophyll content but subsoiling (SS) gave higher leaf-area index (LAI) followed by minimum tillage (MT) and PRBS. Similarly, significantly higher crop-growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were recorded under PRBS and FIRBS but leaf-area rtio (LAR) was higher under SS followed by conventional tillage (CT). The yield attributes like effective tillers and grains/ear were significantly higher under PRBS and FIRBS. These resulted in ~9.5 and 16% higher grain yield of wheat than CT and MT respectively. The harvest index (HI), partial factor productivity (PFP) and nutrient harvest index (NHI) were significantly higher under FIRBS and PRBS tillage systems. Among the nutrient management, recommended dose of fertilizer (RDF) had greater plant height, dry-matter accumulation, chlorophyll content, LAI, CGR, LAR, effective tillers, grains/ear. The grain yield of wheat was 11.7 and 48.6% higher than SSNM and 50% RDF respectively. The HI, PFP and NHI were found significantly higher at 50% RDF followed by site-specific nutrient management (SSNM). Thus, wheat planted either on PRBS or FIRBS with application of recommended dose of fertilizers 150 kg N+26.4 kg P + 33.3 kg K/ha may be used for higher productivity, profitability and resource-use efficiency of wheat in *tarai* region of Uttrakhand and also be replicated in similar agro-ecology of India.

Key words: *Effective tillers, Growth analysis, Harvest index, Partial factor productivity, Tillage*

Presently wheat is cultivated on an area of 31.0 million hectare (m ha) with 101.2 million tonnes production in India (AICWBIP, 2019) and also covers its highest area under rice-wheat system that occupies 14 m ha in South Asia including India and Pakistan (Usman *et al*., 2013), and excessive use of exploitation of tillage implements, fertilizers and pesticides results in degraded natural resources like organic matter (Fan *et al*., 2005) and low grain yield of the system (Chhokar *et al*., 2007). Normally wheat is sown from mid-October to mid-November in North-West India but in few patches, its sowing is delayed due to late harvest of either rice or some other crops like cotton, vegetable pea, *toria* and ratoon sugarcane (Ram, 2020). Wheat yield reduced by 1–1.5%/ha/day, if planted after 15th November (Gangwar *et al*., 2006), mainly due to increased temperature at flowering and grain-filling stages (Song *et al*., 2015). In general, late sowing of wheat varieties faces severe temperature stress which shortens the heading and maturity duration, ultimately affecting grain yield (Ram *et al.,* 2017).

Conservation agriculture is an alternative to address the problems associated with conventional agriculture (Bhan and Bahera, 2014). Therefore the conservation tillage practices are viable options for the farmers not only in terms of energy and time efficiency but also for attaining higher productivity and profitability (Kumar *et al*., 2013). It also

[2]**Correspondence author's Email:** drmspal1@gmail.com

[1]Ph.D. (Agronomy) Student; [2]Professor (Agronomy), College of Agriculture, Department of Agronomy, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

improves water-and nutrient-use efficiencies, increases crop productivity and carbon sequestration, ameliorates soil properties and mitigates greenhouse gases emission (Singh and Malhi, 2006).

Since wheat is the second most important staple food of India, its sustainable production makes country self sufficient in foodgrain production. However, its area expansion is almost difficult, leaving only option of improving the productivity though poor soil health coupled with inappropriate nutrient management are major bottlenecks for realizing the production potentials of crop varieties (Majumdar *et al*., 2012). The yield plateau in most-productive wheat ecologies (north-west India) and large management yield gaps (~50%) in eastern India are major concerns for future food security of the country. In addition to natural resource depletion and biotic-abiotic stresses, the multiple-nutrient deficiencies are the key factors that contribute not only to yield plateaus but also to declining factor productivity, shrinking profits and environmental footprints (Majumdar *et al*., 2019). It is a general trend that farmers apply excess nitrogenous fertilizers only and very less phosphatic and potassic fertilizers and almost none micronutrients that disturb the soil natural, C : N and N : P : K ratio. Recent approaches like site-specific nutrient management (SSNM) and soil test-based recommended dose of fertilizers provide an opportunity to feeding crops with nutrients as and when they are needed and hence making synergy for nutrient demand and supply under a certain production system. Therefore, the balanced fertilization is envisaged to sustain wheat production and soil health. The current paper aims at analyzing the tillage-and nutrient-management effects on growth, yield and resource-use efficiency of wheat in foothills (*tarai)* region of Uttarakhand, so that tillage-and nutrient-management strategy may be standardized for boosting wheat production in the region.

MATERIALS AND METHODS

The field experiment was carried out during 2013–14 and 2014–15 at the Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (29ˆN, 79.5ˆE, 243.84 m above mean sea-level) Uttarakhand, representing the *tarai* belt of Uttarakhand in Indo-Gangetic plains of India. The experimental site was silty clay loam, having soil *p*H 7.21, organic carbon 0.684% and 242.42, 22.56 and 240.32 kg/ha available nitrogen, phosphorus and potash respectively. The experiment was laid out in split-plot design with 18 treatments with 6 tillage options, i.e. furrow-irrigated raised bed system (FIRBS), conventional tillage (CT), sub soiling (SS), zero tillage (ZT), minimum tillage with 2 pass of rotavator (MT) and permanent raised bed system (PRBS) in main plot, and 3 nutrient levels i.e. 50% of recommended dose of fertilizers (50% RDF), site-specific nutrient management (based on nutrient expert for wheat), i.e. 120 kg N + 10 kg P + 37 kg K/ha (SSNM) and 100% recommended dose of fertilizer, i.e. 150 kg N + 26.4 kg P + 33.3 kg K/ha (RDF) in subplot with 3 replications. The FIRBS and PRBS were made with the help of tractor drawn FIRBS and raised bed planter respectively. The Pantnagar subsoiler was used to plough field at depth of 60 cm below soil surface before crop sowing under SS treatments. Only single pass of Pantnagar zero tillage was used under ZT for crop sowing. The field was ploughed by 1 pass of common plough followed by 2 pass of rotavator under CT, but only 1 pass of rotatvator was allowed under MT. The raised beds and FIRBS were maintained continuously for 2 years. Maize was grown in season during both years of field experimentation.

The crop was grown as per recommended practices. The wheat variety 'UP 2748' and 'PBW 550' was planted in 2013 and 2014, respectively, mainly because of seed unavailability of var. 'UP 2748' in 2nd year field experiment. The fertilizer dose, i.e. N : P : K applied was 150 : 26.4 : 33 under 100% RDF, 120 : 8.7 : 30.8 under SSNM and 75 : 13.2 : 16.5 kg/ha under 50% RDF. The fertilizer dose under SSNM was estimated based on decision-support system on nutrient management of wheat developed by IPNM. One-third nitrogen (N) and full dose of phosphorus and potash was applied basal and remaining N was top-dressed in 3 equal splits- at critical-root initiation, tillereing and flowering stages respectively. The crop samples of 5 plants were collected from the second row of each plot at different growth stages and analyzed for different attributes. The growth parameters like plant height, dry-matter accumulation, leaf area, leaf-area index, growth analysis like mean crop-growth rate ($\overline{\text{CGR}}$), relative growth rate ($\overline{RGR}$), net assimilation rate ($\overline{NAR}$) and leaf-area ratio ($\overline{LAR}$) at different growth stages, grain yield and economics were studied. At harvesting, the net plot was harvested and grain yield was converted into tonnes/ha. The minimum support price of grain and prevailing rates of straw was taken for calculation of cost of cultivation and gross returns. The resource-use efficiency, i.e. partial factor productivity (PFP) and nutrient harvest index (NHI), were estimated as:

$$\text{PFP} = \frac{\text{Grain Yield (kg/ha)}}{\text{Amount of nutrient applied (kg/ha)}}$$

$$\text{NHI} = \frac{\text{Nutrient uptake in grains (kg/ha)}}{\text{Total nutreint uptake (grains+straw) (kg/ha)}}$$

RESULTS AND DISCUSSION

Effect of Tillage

Growth attributes: Tillage had a significant effect on plant height of wheat (Table 1). The pooled values of plant height indicated that, the tallest plants were recorded in PRBS that was significantly similar to FIRBS, SS and MT and CT. the ZT had significantly shortest plants. Greater availability of nutrient and moisture under FIRBS and PRBS made better plant height but shortest plant height under ZT might be caused due to high bulk density leading to poor root development (Chaplain *et al*., 2011). Singh *et al.* (2011) also reported taller plants under ridge planting.

Dry-matter accumulation of plant was significantly influenced by tillage methods (Table 1). Pooled values of 2 years indicated that, PRBS resulted in significantly highest dry-matter accumulation followed by ZT, CT, FIRBS and MT. The higher dry-matter accumulation was attributed possibly owing to better soil physical condition and availability of moisture and nutrient leading to higher plant height and more tillers/unit area. Our results confirm the findings of Shakeel *et al*. (2014).

The chlorophyll content is an indicator of plant health, so the SPAD values were recorded at 90 days after sowing (DAS) as it is the peak growth stage of wheat. Tillage options had significant effect on chlorophyll content, i.e. SPAD reading at 90 DAS (Table 1). The pooled chlorophyll content was recorded significantly higher under MT, being significantly at par with FIRBS and CT. The higher SPAD values were attributed to better plant growth and greenness in leaves. Bhatt (2015) also reported higher green seeker values under ZT at 90 DAS. Leaf-area index (LAI) differed significantly among tillage options during both years and pooled LAI was significantly highest under SS at 90 DAS. In general, PRBS, MT, and FIRBS had higher LAI but ZT the lowest mainly due to poor growth of the plants resulting low leaf area. Higher leaf-area index was owing to taller plants, more leaves and their leaf area. Shakeel *et al.* (2014) also reported similar findings.

Growth analysis

The PRBS and ZT had the highest and the lowest mean CGR, respectively, at 30–60 DAS during both the years. The pooled values also followed the above trend. Similarly the highest and the lowest mean CGR at 60 DAS-harvest was found in SS and FIRBS, respectively, during 2013. In 2014, FIRBS exhibited the highest values and CT the lowest value. The pooled values indicated that the highest and the lowest mean CGR values were recorded under SS and CT respectively (Fig.1a).

At 30–60 DAS, higher mean RGR was recorded under FIRBS that was very close to that under PRBS and CT, but the lowest RGR was found under SS in 2013. Similarly, the higher RGR was noticed under PRBS and the lowest in FIRBS in 2014. The pooled values revealed that, PRBS had the highest mean RGR followed by CT. At 60 DAS-harvest, mean RGR was recorded highly variable under different tillage options, however the highest and the low-

Table 1. Effect of tillage and nutrient management on plant height, dry-matter accumulation, SPAD and leaf-area index (LAI) of wheat during 2013–14 and 2014–15 (pooled of 2 years)

Treatment	Plant height at harvesting (cm)	Dry-matter accumulation (g/m^2)	SPAD values (90 DAS)	LAI (90 DAS)
Tillage method (T)				
FIRBS	79	1,420	31.20	3.21
CT	78	1,435	30.31	3.55
SS	79	1,397	29.88	3.82
ZT	76	1,441	24.90	3.02
MT	79	1,420	31.43	3.56
PRBS	80	1,494	29.25	3.54
SEm±	0.57	1,.30	0.43	0.03
CD (P=0.05)	02	04	1.35	0.08
Nutrient management (N)				
50% RDF	21	1,291	27.27	2.90
SSNM	22	1,417	28.72	3.48
RDF	24	1,596	31.24	3.97
SEm±	0.27	0.84	0.38	0.03
CD (P=0.05)	01	02	1.10	0.08
Interaction (T×N)	NS	S	NS	S

SPAD, Soil Plant Analysis Development; DAS, days after sowing
FIRBS, Furrow irrigated raised bed system; CT, conventional tillage; SS, subsoiling; ZT, zero tillage; MT, minimum tillage; PRBS, permanent raised bed system; SSNM, site-specific nutrient management; RDF, recommended dose of fertilizer

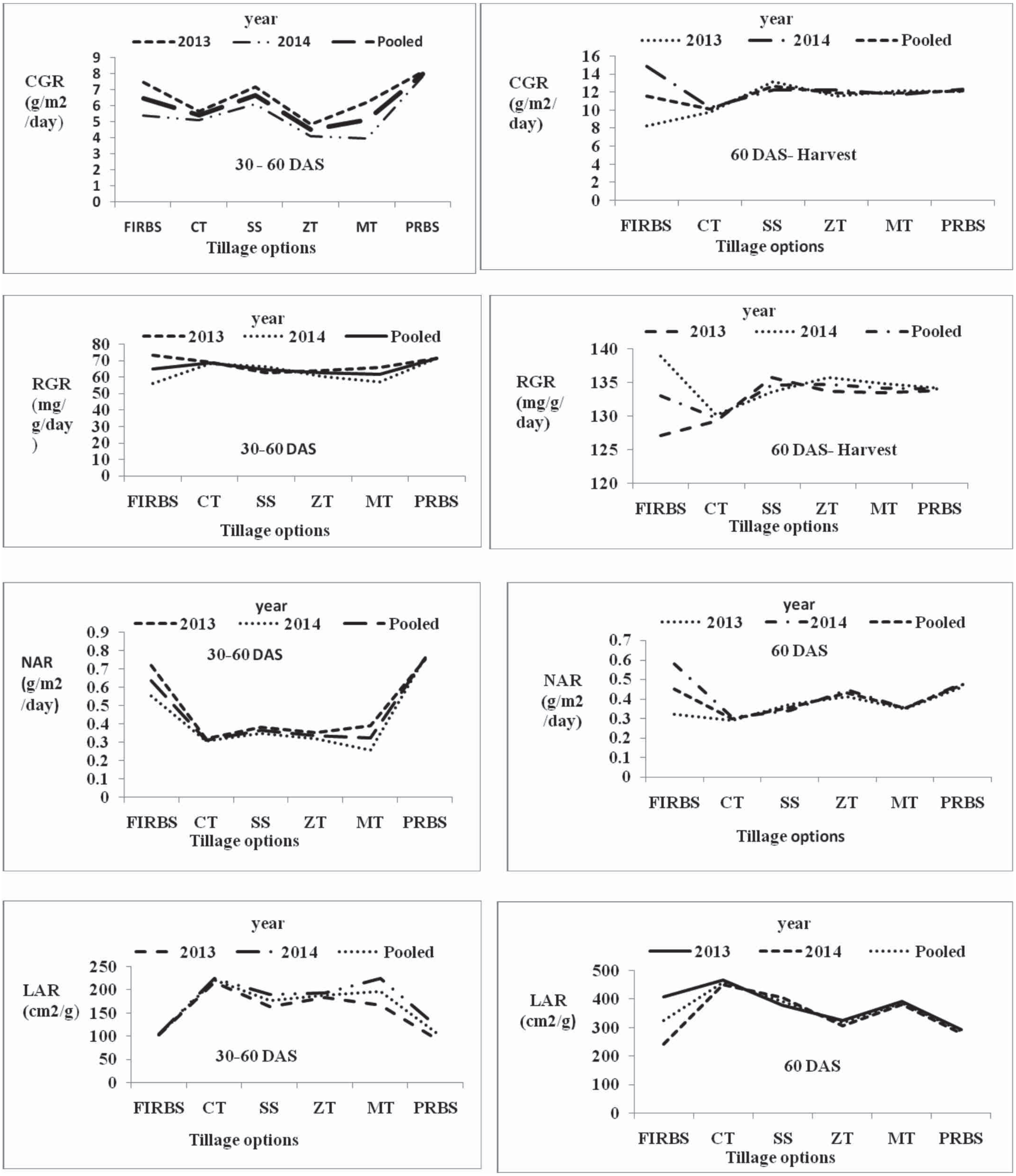

Fig. 1. Effect of tillage on mean CGR (g/m^2/day), RGR (mg/g/day), NAR (g/m^2/day) and LAR (cm^2/g) of wheat at 30–60 days after sowing and 60 days after sowing to harvesting stage (CGR, Crop growth rate; RGR, relative growth rate; NAR, net assimilation rate; LAR, leaf-area ratio)

est mean RGR were noticed PRBS and FIRBS, respectively. in 2013 but in 2014, the FIRBS and CT resulted in the highest and lowest RGR respectively. The pooled values showed that ZT and CT had the highest and the lowest mean RGR (Fig.1b). The mean NAR was higher under PRBS and the lowest under CT at both 30–60 DAS and 60 DAS-harvest stages during both the years and in the pooled values except in 2014 where MT recorded the highest NAR under FIRBS at 30–60 DAS (Fig.1c). The mean LAR was the highest in CT and the lowest in FIRBS during at 30–60 DAS both the years. The LAR at 60 DAS-harvest was the highest and lowest under CT and PRBS in 2013 and CT and FIRBS in 2014 respectively. The pooled LAR was also significantly highest under CT and the lowest under PRBS. The differential values of growth analysis were due to variation in leaf area and dry-matter accumulation under different tillage methods.

Yield attributes and grain yield: The effective tillers varied significantly among tillage methods (Table 2). On pooled basis, significantly highest and the lowest effective tiller/m^2 were observed under PRBS. The PRBS showed 4.7, 9.6, 24.1, 31.5 and 60.6% higher number of effective tillers/m^2 than SS, FIRBS, MT, CT and ZT respectively. The highest number of grains/ear was found under PRBS and FIRBS that were significantly equal to SS and the lowest value was recorded in ZT (Table 2). The higher values of effective tillers and number of grains/ear were the result of more LAI and dry-matter accumulation. Our result confirm those of Hossain (2006).

The grain yield of wheat varied significantly among tillage options (Table 2). The highest grain yield of wheat was recorded under PRBS, being almost equal to FIRBS and it was 9.5 and 16.0% greater than CT and MT respectively. The higher grain yield of wheat was the result of more effective tillers/m^2 and number of grains/ear. Wheat planting on beds and nitrogen application at 120 kg/ha resulted in 15.06% higher grain yield than flat planting at the same nitrogen rate (Singh *et al*., 2011; Majeed *et al.,* 2015).

Harvest index: Tillage had significant effect on harvest index (HI) of wheat (Tabale 2). On pooled basis, HI was significantly highest under FIRBS followed by PRBS, SS and CT. The harvest index was the highest in FIRBS mainly because of higher economic yield of wheat and lower biological yield compared to other tillage systems. Our similar findings were confirm the results of Hobbs *et al*. (2000) and Hossain (2006) who also reported higher harvest index under reduced tillage.

Partial factor productivity: The partial factor productivity (PFP) was influenced greatly by tillage methods (Table 3). The highest PFP was estimated under PRBS that had 2.3, 7.1, 9.4, 17.7% higher values than SS, FIRBS, MT, CT and ZT respectively**.** Higher PFP was the result of higher contribution to economic yield by unit nutrient applied. Majeed *et al.* (2015) found 29.83% higher N recovery and 14.59% higher N agronomic efficiency under bed planted compared to flat-planted wheat.

Nutrient harvest index: The nutrient harvest (NHI) index

Table 2. Effect of tillage and nutrient management on effective tillers, number of grains/ear grain yield and harvest index of wheat during 2013–14 and 2014–15 (pooled data of 2 years)

Treatment	Effective tillers/m^2	Grains/year	Grain yield (t/ha)	Harvest index (%)
Tillage method (T)				
FIRBS	324	41.0	3.78	45.0
CT	270	37.0	3.45	42.2
SS	339	39.0	3.75	42.4
ZT	221	35.0	3.25	42.0
MT	286	38.0	3.51	42.0
PRBS	355	41.0	3.79	42.4
SEm±	1.30	0.7	0.06	0.003
CD (P=0.05)	04	2.3	0.19	0.01
Nutrient management (N)				
50% RDF	269	35.0	2.82	43.4
SSNM	298	39.0	3.76	42.4
RDF	332	42.0	4.19	42.3
SEm±	0.3	0.4	0.04	0.003
CD (P=0.05)	01	1.2	0.12	0.01
Interaction(T×N)	S	S	2.82	NS

SPAD, Soil Plant Analysis Development; DAS, days after sowing
FIRBS, Furrow irrigated raised bed system; CT, conventional tillage; SS, subsoiling; ZT, zero tillage; MT, minimum tillage; PRBS, permanent raised bed system; SSNM, site-specific nutrient management; RDF, recommended dose of fertilizer

differed significantly among the tillage options (Table 2). The pooled NHI was also significantly highest under FIRBS followed by CT and PRBS, but the lowest was noticed under MT. The higher values of NHI were attributed to higher HI and nutrient uptake.

Economics: The gross and net returns were affected significantly by tillage methods (Table 3). Pooled data of 2 years indicated that significantly highest gross returns were recorded under PRBS that were non-significant with SS and FIRBS but significantly lowest gross returns were found under ZT. The net returns showed similar trend with significantly higher value under PRBS that had 1.0 and 4.1% higher values than SS and FIRBS respectively. The higher net returns were attributed to higher economic yield/ unit cost of production. Kumar *et al.* (2013) concluded that, reduced tillage resulted in 20% higher net returns than conventional tillage.

Effect of nutrient management

Growth attributes: The growth attributes, i.e. plant height, dry-matter accumulation and LAI, were affected significantly by the tillage methods (Table 1). The plant height of wheat on pooled basis was significantly highest under RDF followed by SSNM and the lowest in 50% RDF. The RDF resulted in tallest plants mainly because of better nutrient availability and its utilization for plant growth and development as reported by Majeed *et al.* (2015). The RDF also resulted in significantly highest dry-matter accumulation followed by SSNM and the lowest under 50% RDF mainly because of more plant height, LAI and effective tillers/unit area. The results confirm the findings of Kumar *et al*. (2013).

The RDF also showed significantly highest SPAD values or leaf greenness, while 50% RDF the lowest value. The higher SPAD value under RDF followed by SSNM was possibly due to more absorption of nutrients including nitrogen at higher dose of fertilization. Bhatt (2015) also found higher SPAD and green-seeker values at recommended NPK followed by SSNM. The LAI was significantly highest under RDF. Revealing 14.1 and 36.9% higher values than SSNM and 50% RDF respectively. The higher LAI was contributed by taller plants with more leaf area. Tillage and nutrient levels had significant interaction on dry-matter accumulation and LAI.

Growth analysis: The growth analysis like mean CGR, RGR, NAR and LAR varied greatly with nutrient management (Figs. 1 and 2). The mean CGR at both 30–60 DAS and 60 DAS-harvest was the highest at RDF during both the years as well as pooled values (Fig. 2a). The highest mean RGR at 30–60 DAS was recorded under RDF followed by with SSNM and 50% RDF during 2013 but in 2014, the highest RGR was observed under SSNM and the lowest at RDF. The pooled values revealed that SSNM had the highest mean RGR followed by 50% RDF and the lowest at RDF. At 60 DAS-harvest, the highest RGR was observed under SSNM followed by RDF and the lowest value under 50% RDF (Fig. 2b). The 50% RDF and SSNM had the highest NAR at 30–60 DAS and 60 DAS-harvest, re-

Table 3. Effect of tillage and nutrient management on partial factor productivity (PFP), nutrient harvest index (NHI) and economics on wheat during 2013 and 2014 (pooled data of 2 years)

Treatment	PFP (kg/ha)	NHI	Gross return (× 10^3 ₹/ha)	Net returns (× 10^3₹/ha)
Tillage options (T)				
FIRBS	19.64	0.446	60,678	25,243
CT	18.83	0.428	56,234	22,299
SS	20.56	0.417	60,945	26,010
ZT	17.87	0.417	53,082	20,662
MT	19.23	0.409	57,107	24,672
PRBS	21.03	0.418	61,704	26,269
SEm±	0.70	0.005	903	903
CD (P=0.05)	NS	0.014	2,845	2,845
Nutrient levels (N)				
50% RDF	21.96	0.432	45,735	12,924
SSNM	19.87	0.417	61,025	27,106
RDF	16.75	0.419	68,114	32,547
SEm±	0.44	0.004	570	570
CD (P=0.05)	1.30	0.011	1,664	1,664
Interaction (T×N)	S	NS	NS	NS

FIRBS, Furrow irrigated raised bed system; CT, conventional tillage; SS, subsoiling; ZT, zero tillage; MT, minimum tillage; PRBS, permanent raised bed system; SSNM, site-specific nutrient management; RDF, recommended dose of fertilizer
Minimum support price for wheat = ₹1,400/q and ₹1,450/q for 2013–14 and 2014–15, respectively

spectively, during both the years and pooled values (Fig. 2c). The highest mean LAR was recorded under RDF at both 30–60 DAS and 60 DAS-harvest stages during both years and pooled values (Fig. 2d). The plant growth including plant height, dry-matter accumulation and leaf-area index were higher at higher nutrient management levels that facilitated to higher growth analysis.

Yield attributes and grain yield: The pooled values of yield attributes like effective tillers/m^2 and grains/ear differed with nutrient management levels (Table 2). The RDF

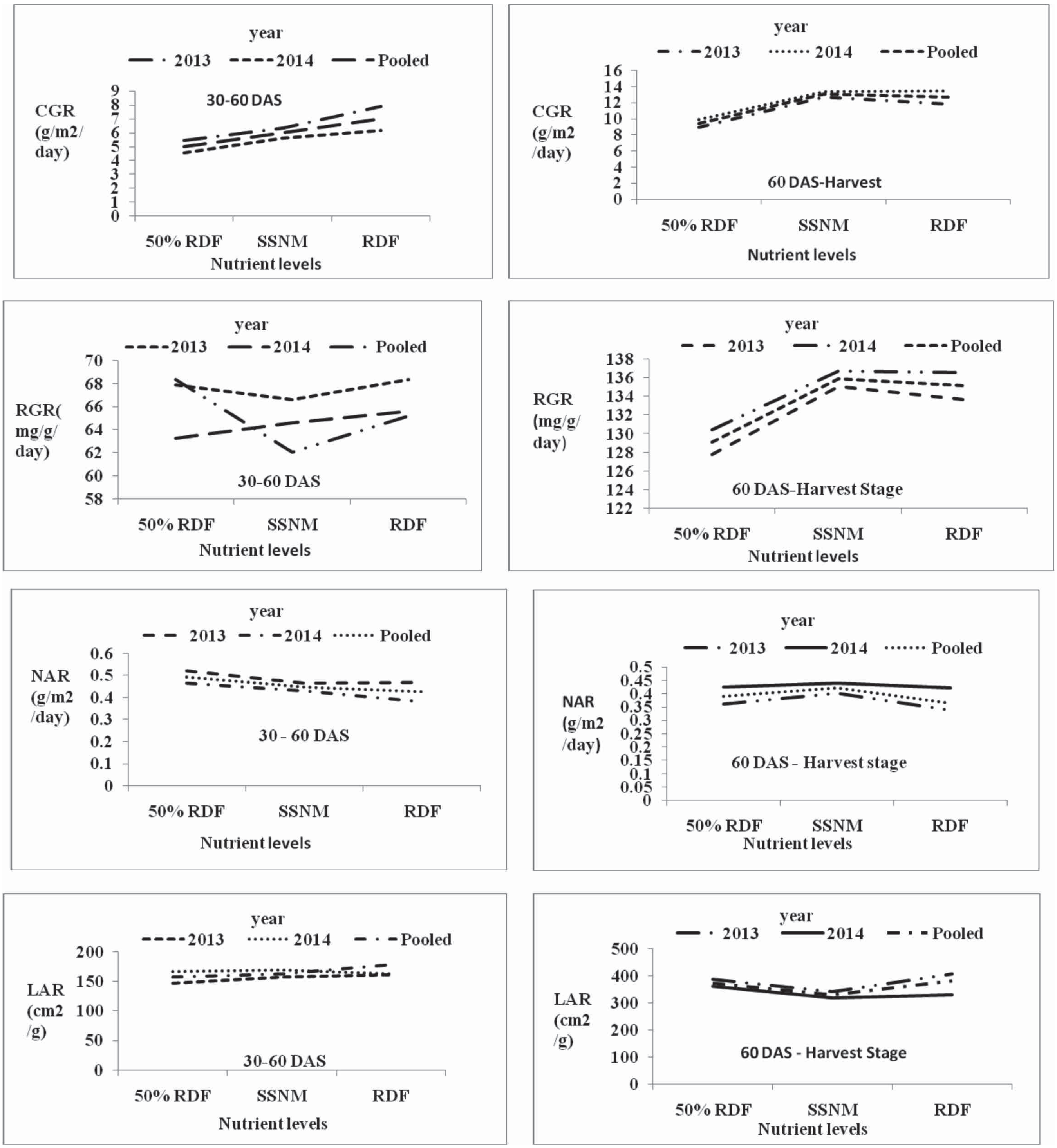

Fig. 2. Effect of nutrient management on mean CGR (g/m^2/day), RGR (mg/g/day), NAR (g/m^2/day) and LAR (g/m^2/day) of wheat at 30–60 days after sowing and 60 days after sowing to harvesting stage (CGR, Crop growth rate; RGR, relative growth rate; NAR, net assimilation rate; LAR, leaf-area ratio)

resulted in significantly highest effective tillers/m^2, being 11.5 and 23.4% more than SSNM and 50% RDF respectively. Similarly, the grains/ear were significantly highest under RDF with 7.7 and 20.0% higher than SSNM and 50% RDF respectively. Higher dose of fertilizers resulted in more effective ears which led to more grains/ear. Ram (2020) concluded that, RDF + 10 t FYM/ha resulted in higher effective tillers than alone application of RDF. The tillage and nutrient management had significant interaction on effective tillers/m^2 and grains/ear.

The nutrient management had significant effect on grain yield of wheat (Table 2). The pooled gain yield was also significantly highest under RDF, with 11.4 and 48.6% greater over SSNM and 50% RDF respectively. The higher grain yield was the result of better growth and yield attributes. Limon *et al*. (2000) and Honalli and Chittarur (2013) reported similar results. Interaction effect was found non-significant.

Harvest index: The harvest index (HI) differed significantly among the nutrient-management levels (Table 2). On pooled basis, the significantly highest HI was noted at 50% RDF followed by SSNM; however, it was at par with RDF. The higher HI at lower dose of fertilizer was the result of comparatively higher per cent increase in economic yield/unit of fertilizer applied than biological yield. Borse *et al*. (2019) reported that, RDF resulted in higher HI than 80% RDF. It was not affected by interaction effect.

Partial factor productivity: The nutrient levels had significant effect on partial factor productivity (PFP) of wheat and the highest and the lowest PFP were recorded at 50% RDF and RDF respectively (Table 3). The 50% RDF ensued 10.5 and 31.1% higher PFP than SSNM and RDF respectively. It indicates that an increment grain yield per unit nutrient applied under 50% RDF was greater than other levels of nutrient management, i.e. SSNM and RDF. Majeed *et al.* (2015) reported higher N-use efficiency at 60 kg N/ha than 100 and 120 kg N/ha. Interaction effect was also found non-significant between tillage option and nutrient levels.

Nutrient harvest index: The nutrient harvest index (NHI) was influenced significantly by nutrient management option (Table 3). The pooled NHI was significantly highest at 50% RDF, while both SSNM and RDF were at par in respect of pooled NHI.

Economics: The nutrient management had significant impact on gross and net returns (Table 3). The RDF resulted in significantly highest gross and net returns being 11.6 and 48.9% higher gross and 20.0 and 154.7% higher net returns than SSNM and 50% RDF respectively. The higher economic values were attributed to more grain yield and lower cost of production. Tillage options and nutrient levels had non-significant interaction effect on gross and net returns.

It is therefore concluded that, wheat crop may be planted either on FIRBS or permanent raised bed system (PRBS) with application of recommended dose of fertilizers 150 kg N + 26.4 kg P + 33.3 kg K/ha for higher productivity, profitability and resource-use efficiency in *tarai* region of Uttrakhand and also be replicated in whole Indo-Gangetic plains of India.

REFERENCES

AICWBIP. 2019. *Progress Report of All India Coordinated Wheatand Barley Improvement Project 2018–19: Director's Report.* Singh, G.P. (Ed.). ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India, 72 pp.

Bhan, S. and Bahera, U.K. 2014. Conservation agriculture in India – Problems, prospects and policy issues. *International Soil and Water Conservation Research* **2**: 1–12**.**

Borse, D.K., Usadadia, V.P. and Thorave, D.S. 2019. Nutrient management in wheat (*Triticum aestivum* L.) under partially reclaimed coastal salt affected soil of south Gujarat. *International Journal on Current Microbiology and Applied Sciences* **8**(5): 1,590–1,599.

Bhatt, P. 2015. Studies on precision nutrient management under different tillage practices in wheat. M.Sc. (Agronomy) Thesis, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, 120 p.

Chaplain, V., Defossez, P., Richrad, G, Tessier, D. and Roger-Estrade, J. 2011. Contrasted effects of no-till on bulk density of sol and mechanical resistance. *Soil and Tillage Research* **111**: 105–114.

Chhokar R.S., Sharma, R.K., Jat, G.R., Pundir, A.K. and Gathala, M.K. 2007. Effect of tillage and herbicides on weeds and Productivity of Wheat under rice–wheat growing system. *Crop Protection* **26**: 1,689–1,696.

Fan, M., Jiang, R.X., Liu, Zhang, Lu, F., Zeng, S.X. and Christie, P. 2005. Interactions between non-flooded mulching cultivation and varying nitrogen inputs in rice–wheat rotations. *Field Crops Research* **91**: 307–318.

Gangwar, K.S., Singh, K.K., Sharma, S.K. and Tomar, O.K. 2006. Alternative tillage and crop residue management in wheat after rice in sandy loam soils of Indo-Gangetic Plains. *Soil and Tillage Research* **88**: 242–252.

Hobbs, P.R., Singh Y., G.S., Giri, J.G.L and Dusbury, J.M. 2000. Direct seeding and reduced tillage options in the rice–wheat system of the Indo-Gangetic plains of South Asia. Paper presented at International Rice Research Institute, Workshop, Bankok, Thiland, 25–28 January 2000.

Honalli, S. N and Chittarur, B.M. 2013. Productivity of wheat as influenced by leaf color chart nutrient management. *Karnataka Agricultural Sciences* **24**: 554–558.

Hossain. 2006. Effect of planting method and nitrogen on yield and yield attributes of wheat. *Journal of Biological Sciences* **14**: 127–130.

Kumar, V., Yashpal, S., Saharawat, M., Gathala, K., Jat, A.S., Singh, S.K., Chaudhary, N. and Jat, M. L. 2013. Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in the Indo-Gangetic Plains. *Field Crops Research* **142**: 1–8.

Limon, O.A.L., Sayree, K.D. and Francis, C.S. 2000. Wheat nitrogen use efficiency in a bed planting system in north west Mexico. *Agronomy Journal* **92**: 303–308.

Majeed, A., Muhmood, A., Niaz, A., Javid, S., Ahmad, Z.A., Shah, S.S.H. and Shah A.H. 2015. Bed planting of wheat (*Triticum aestivum* L.) improves nitrogen use efficiency and grain yield compared to flat planting. *The Crop Journal* **3**: 118–124.

Majumdar, K., Jat, M.L., Pampolino, M., Kumar, A., Shahi, V., Gupta, N., Singh, V., Satyanarayana, T., Dwivedi, B.S., Singh, V.K., Kumar, D., Kamboj, B.R., Sidhu, H.S., Meena, M.C. and Johnston, A. 2012. Economics of potassium fertilizer application in rice, wheat and maize grown in the Indo-Gangetic Plains. *Indian Journal of Fertiliser* **8**(5): 44–53.

Majumdar, K, Jat, M.L., Pampolino, M., Satyanarayana, T., Dutta, S and Kumar, A. 2019. Nutrient management in wheat: current scenario, improved strategies and future research needs in India. *Journal of Wheat Research* **4**: 1–10.

Ram, Hari. 2020. Mulching, farmyard manure and exogenous application of osmo-protectants confer terminal heat tolerance in wheat (*Tritcum aestivum*). *Indian Journal of Agronomy* **65**(3): 271–277.

Ram, H., Gupta, N., Mavi, G.S., Sarlach, R.S. and Singh, G. 2017. Phenology, photo-thermal units requirement and productivityof wheat varieties as influenced by sowing dates under irrigated conditions in Punjab. *Journal of Crop and Weed* **13**: 73–77.

Shakeel, A., Anjum, E., Umair, A., Mohasin T., Rafi Q. and Imran. K. 2014. Morphplogical and phonological attributes of maize affected by different tillage practices and varied sowing methods. *American Journal of Plant Sciences* **5**: 1,657–1,664.

Singh, B. and Malhi, S.S. 2006. Response of soil physical properties to tillage and residue management on two soils in a temperate environment. *Soil and Tillage Research* **85**: 143–153.

Singh, Y.V., Dhar, D.W. and Agarwal, B. 2011. Influence of organic nutrient management on basmati rice (*Oryza sativa*)–wheat (*Triticum aestivum*)–greengram (*Vigna radiata*) cropping system. *Indian Journal of Agronomy* **56**: 169–175.

Song, W.F., Zhao, L.J., Zhang, X.M., Zhang, Y.M., Li, J.L., Zhang, L.L., Song, Q.J., Zhao, H.B., Zhang, Y.B., Zhang, C.L., Xin,W.L., Sun, L.F. and Xiao, Z.M. 2015. Effect of timing of heatstress during grain filling in two wheat varieties under mod-erate and very high temperature. *Indian Journal of Genetics and Plant Breeding* **75**: 121–124.

Usman, Khalid, Khan, Ejaz Ahmad, Khan, Niamatullah, Khan, M.N, Ghulam, Said, Khan, Sarfaraz and Baloch, Jalaluddin. 2013. Effect of tillage and nitrogen on wheat production, economics, and soil fertility in rice–wheat Cropping System. *American Journal of Plant Sciences* **4**: 17–25.