

Research Article

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Available plant nutrients in soil as influenced by planting methods and herbicidal treatments

<https://doi.org/10.1515/opag-2019-0031>

received July 28, 2018; accepted December 13, 2018

Abstract: Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) is the predominant cropping system of North Indian region. Due to continuous following of rice-wheat cropping system every year, weed infestation particularly in wheat, has emerged a major problem resulting in reduced wheat yield and nutrient mining. Integration of suitable planting methods, along with effective weed control measures, can reduce the weed infestation and nutrient mining from the soil and can enhance available plant nutrients in the soil. To evaluate the influence of different planting techniques and weed control practices in wheat on available plant nutrients in soil, a field study was conducted at the department of Agronomy, Punjab Agricultural University, Ludhiana (India) for two consecutive years. The treatments comprised of five planting techniques: conventional tillage, zero till sowing without rice stubbles, zero till sowing in standing rice stubbles, zero till sowing after partial burning of rice stubbles and bed planting and five weed control treatments i.e. clodinafop 60 g/ha, clodinafop 60 g/ha fb 2, 4-D 0.5 kg/ha, sulfosulfuron 25 g/ha, mesosulfuron + iodosulfuron 12 g/ha and unweeded (control). The experiment was conducted in split plot design with planting methods in the main plot and herbicidal treatments in the sub plot with three replications. The results of the study showed that zero till sowing of wheat in standing rice stubbles observed significantly higher soil organic carbon, available nitrogen, phosphorus and potassium than conventional till wheat sowing after removal of rice residues. Although partial burning of rice stubbles also showed positive trend in soil organic carbon, available nitrogen, phosphorus and potassium but retort was less distinct than rice stubbles without burning. Further, zero tillage alone also showed

improvement in soil organic carbon and available nitrogen, phosphorus and potassium over conventional tillage. Application of herbicides did not diverge soil organic carbon, but significantly improved the available nitrogen, phosphorus and potassium content in soil than the unweeded (control).

Keywords: Organic carbon, Available nitrogen, Available phosphorus, Available potassium, Wheat, Broadleaf weeds, *Phalaris minor*, Grass weed

1 Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crops grown in the world. India has reached the prestigious position in the world in wheat production due to the innovation of high yielding dwarf genotypes, improved fertilization plant protection measures and irrigation facilities coupled with scientific research. Rice (*Oryza sativa* L.)-wheat is the predominant cropping system of Punjab, India. Due to following same rice-wheat cropping system every year, wheat is particularly infested by diverse weed flora including both grass and broadleaf weeds, causing yield reduction of 15-40 percent depending upon category and strength of their incursion (Jat et al. 2004). Uptake of nutrients by weeds is comparatively faster and larger than crops, resulting in nutrient mining and reduction in available plant nutrients in soil. Integration of suitable planting methods and herbicides can effectively manage weeds. Different planting methods creates different micro-climatic conditions which may not favor the weed germination and growth. Sowing of wheat under zero till conditions reduced the infestation of grass weeds, whereas, the population of broadleaf weeds was enhanced (Brar and Walia 2007). Similarly, bed planning of wheat providing another type of ecology reduced the infestation and nutrient uptake by weeds (Brar and Walia 2009). In the same way, weeds behaved differently under different load of surface rice residues (Brar and Walia 2010). Regarding the chemical control of weeds, isoproturon and 2, 4-D were most commonly

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used herbicides for the control of grass and broad leaf weeds, respectively. However, their continuous use has either resulted in shift in weed flora or emergence of resistance strains in some species (Yadav et al. 1996). Management of weeds become a major concern due to resistance development in *Phalaris minor* against the most commonly used herbicide isoproturon (Malik and Singh 1995) and increased infestation of broadleaf weeds. This necessitate the use of new herbicide formulation alone or in combination for the control of diverse weed flora of wheat to avoid conspicuous shift in weed flora. Many new herbicides molecules have been synthesized which are quite promising against *P. minor* and broad leaf weeds, but their behavior can vary under different planting methods. The organic carbon associated with the ash of burnt rice straw has been found to be highly absorptive of herbicides (Walia et al. 1999). In another way, the applied herbicide to wheat crop can be intercepted by the standing stubbles of rice. So, the behavior of herbicides may vary under different planting methods of wheat. In view of the above complications, the current investigation was planned to assess the available nutrients in soil under different planting methods and weed control treatments.

2 Materials and Methods

To evaluate the response of planting techniques and weed management methods on available plant nutrients in soil, a field experiment was conducted during 2004-05 and 2005-06 at the experimental farm of the department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India. The physico-chemical analysis of the soil from the experimental field before the start of the experiment (Table 1) showed that the soil was loamy sand in texture with nearly normal in-soil reaction (7.3) and electrical conductivity (0.26 dS/m). The soil was low in available nitrogen with 230 kg/ha, but it was medium in organic carbon with 4.2 g/kg, available phosphorus with 18.6 kg/ha and potassium with 150 kg/ha. Figures 1 and 2 presented the meteorological data recorded at Meteorological Observatory of Punjab Agricultural University, Ludhiana during both the cropping seasons.

Figure 1 showed the range of maximum temperature between 13.2 to 37.6°C whereas minimum temperature ranged between 5.3 to 17.4°C during 2004-05. Similarly, Figure 2 depicted the range of the maximum temperature between 16.8 to 35.2°C and minimum temperature between 3.1 to 18.8°C during cropping season 2005-06. However, the maximum and minimum temperature was recorded in the months of April and January, respectively during both the growing seasons. A total rainfall of 186.9 mm and 55.2 mm was recorded during 2004-05 and 2005-06 crop growing seasons, respectively. The experiment was conducted in split plot design with three replications. Five planting techniques viz conventional tillage, zero till sowing without rice stubbles, zero till sowing in standing rice stubbles, zero till sowing after partial burning of rice stubbles and bed planting were assigned in the main plots and five weed control treatments, clodinafop 60 g/ha, clodinafop 60 g/ha fb 2, 4-D 0.5 kg/ha, sulfosulfuron 25 g/ha, mesosulfuron + iodosulfuron 12 g/ha and unweeded (control), were arranged in sub plots.

In case of conventional tillage and bed planting, after the harvest of paddy crop, field was prepared by ploughing twice with disc harrow, and then once with cultivator and finally by planking. Again, two ploughings followed by planking were given after pre-sowing irrigation to prepare a fine seed bed. In case of zero till plots, wheat was directly sown with zero till drill after harvesting the rice; without stubbles, in 1.0 to 1.5' standing stubbles and after partial burning of rice stubbles as per the treatments. In case of bed planting treatment, 67.5 cm wide (37.5 cm bed top and 30 cm furrow) beds were prepared with bed planter. The sowing of wheat was done with tractor drawn conventional drill/zero till/bed planter (2 row per bed) as per treatment during last week of October and first week of November during 2004 and 2005, respectively. Nitrogen (125 kg ha⁻¹) was applied in the form of urea as broadcast in two equal splits, half before sowing and remaining half after first irrigation (25 days after sowing). P₂O₅ (60 kg ha⁻¹) was drilled in the form of diammonium phosphate (DAP) at the time of sowing. Post-emergence application of herbicides; clodinafop 60 g/ha, sulfosulfuron 25 g/ha and mesosulfuron + iodosulfuron 12.0 g/ha was done 35 days

Table 1: Physico-chemical characteristics of the experimental soil

Soil depth (cm)	Texture	pH	EC (dS/m)	Organic carbon (g/kg)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
0-15	Loamy sand	7.32	0.26	4.2	230	18.6	150
15-30	Loamy sand	7.37	0.28	3.3	176	16.0	146

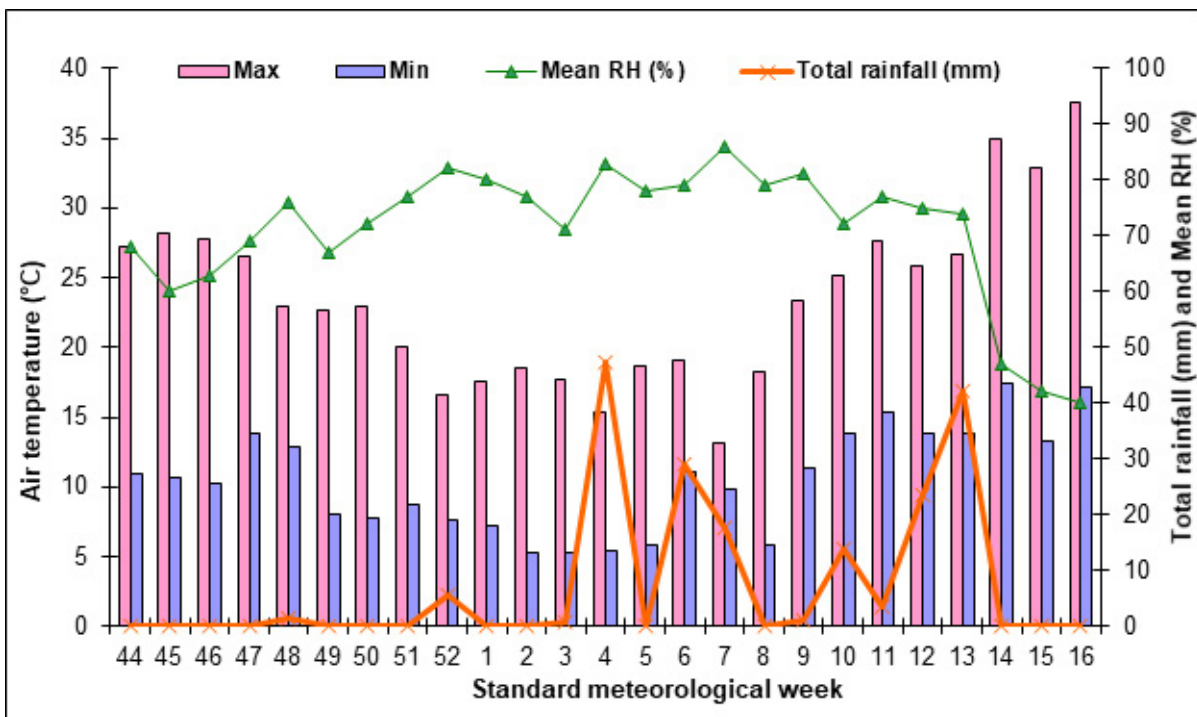


Figure 1: Weekly meteorological data recorded at meteorological observatory at Punjab Agricultural University, Ludhiana during the crop season 2004-2005

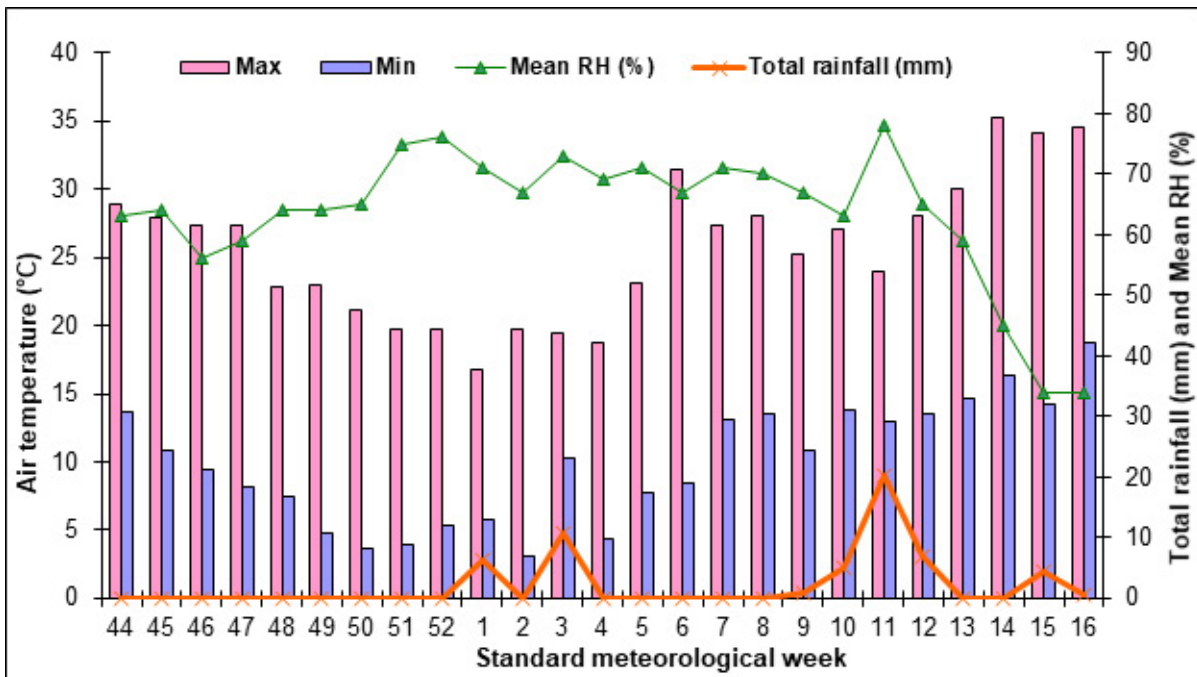


Figure 2: Weekly meteorological data recorded at meteorological observatory at Punjab Agricultural University, Ludhiana during the crop season 2005-2006

after sowing, whereas, 2, 4-D (sodium salt) 0.5 kg/ha was applied one week thereafter. Other crop raising practices were followed as per recommended package of practices.

After harvesting the wheat crop in the month of April, the soil samples were collected for the determination of

organic carbon, available nitrogen, available phosphorus and available potassium from two depths viz., 0-15 cm and 15-30 cm. The soil samples were dried under shade, ground and passed through 2 mm sieve before analysis. Organic carbon was estimated using Walkley and

Black's rapid titration method (Walkley and Black 1934), available nitrogen was determined by modified alkaline potassium permanganate method as given by Subbiah and Asija (1956), available phosphorus was determined as designated by Olsen et al. (1954) and available potassium was extracted with neutral normal ammonium acetate solution as prescribed by Jackson (1967) and determined by flame photometer. The data was analyzed at 5% level of significance by following the statistical procedure prescribed by Cochran and Cox (1967) using package CPCS-1 developed by Cheema and Singh (1991).

Ethical approval: The conducted research is not related to either human or animal use.

3 Results

3.1 Organic Carbon

Soil organic carbon is the backbone of soil fertility. The perusal of data regarding soil organic carbon (Table 2) revealed that retention of rice residues as stubbles and less soil disturbance (zero tillage) showed positive trend

in soil organic carbon. Zero till sowing with standing rice stubbles recorded highest soil organic carbon, whereas, conventional tillage after removing the rice residues recoded least soil organic carbon. The significantly higher soil organic carbon was observed in zero till sowing in standing rice stubbles in 0-15 cm soil layer, than bed planting and conventional tillage during both years of study. Among the zero till plots, although zero till sowing in standing rice stubbles recorded highest organic carbon content but it was statistically at par with other zero till sown plots with no rice residues and partial burnt residues. Less variation was observed in organic carbon at 15-30 cm soil layer, but zero tillage systems were better than conventional tillage and bed planting, but the differences were not significant.

Among the weed control treatments, soil organic carbon content did not show any significant difference during both the years at both the depths (0-15 cm and 15-30 cm) due to different weed control treatments (Table 2). However, herbicide treated plots; mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha, clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha and clodinafop 60 g/ha showed slight improvement in soil organic content than unweeded control plots.

Table 2: Influence of planting techniques and weed control treatments on organic carbon and available nitrogen in soil

Treatment	Organic carbon (g/kg)				Available Nitrogen (kg/ha)			
	2004-05		2005-06		2004-05		2005-06	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Planting techniques								
Conventional tillage	4.4	3.3	4.4	3.3	229	177	231	178
Zero till sowing	4.6	3.4	4.7	3.4	230	178	233	180
Zero till sowing in standing rice stubbles	4.8	3.4	5.0	3.5	237	183	240	185
Zero till sowing after partial burning of rice stubbles	4.7	3.4	4.8	3.5	235	181	238	183
Bed Planting	4.4	3.3	4.5	3.4	234	179	236	181
C D (P=0.05)	0.4	NS	0.5	NS	6.2	4.6	6.6	4.8
Weed control treatments								
Clodinafop 60 g/ha	4.5	3.3	4.6	3.3	230	177	233	179
Clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha	4.6	3.4	4.7	3.5	234	180	236	182
Sulfosulfuron 25 g/ha	4.6	3.4	4.8	3.5	235	182	238	184
Mesosulfuron + iodosulfuron 12 g/ha	4.7	3.4	4.8	3.5	237	184	240	185
Control (unweeded)	4.5	3.3	4.5	3.3	229	175	231	177
C D (P=0.05)	NS	NS	NS	NS	3.8	3.2	4.4	3.3

3.2 Available Nitrogen

Comparing all the planting techniques used, the data (Table 2) showed that the highest available nitrogen was recorded with zero till sowing in standing rice stubbles and lowest with conventional tillage without any rice residue treatment. During first year of study, zero till sowing in standing rice stubbles recorded significantly higher available nitrogen in soil than conventional tillage treatment at both 0-15 cm and 15-30 cm soil depths. During second year, both zero till sowing in standing rice stubbles and zero till sowing after partial of stubbles recorded significantly higher available nitrogen content in soil than conventional tillage at both the soil depths (0-15 cm and 15-30 cm). Further, zero till sowing treatments with or without rice stubbles and bed planting treatment were statistically at par with each other at both the soil depths during both the years.

In the weed control treatments, mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha, clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha observed significantly higher available nitrogen than clodinafop 60 g/ha alone and

unweeded control treatments (Table 2). The trend of available nitrogen in soil was similar during both the growing seasons at both 0-15 cm and 15-30 cm soil depths.

3.3 Available Phosphorus

Available phosphorus in soil was significantly different with different planting techniques during both the years at both the soil depths. Soil samples analyzed after the harvest of wheat crop (Table 3) depicted that zero till sowing of wheat recorded highest available phosphorus in soil at both the soil depths during both the years. At 0-15 cm soil depth, alone zero till sowing of wheat in standing stubbles during first year and both zero till sowing of wheat in standing stubbles as well as after partial burning during second year registered significantly higher available phosphorus content in soil than conventional tillage treatment. All the zero till and bed planting treatments were statistically at par with each other. However, at 15-30 cm soil depth, zero till sowing of wheat in standing stubbles, the partial burning and

Table 3: Influence of planting techniques and weed control treatments available phosphorus and potassium in soil

Treatment	Available Phosphorus (kg/ha)				Available Potassium (kg/ha)			
	2004-05		2005-06		2004-05		2005-06	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Planting techniques								
Conventional tillage	19.2	16.1	19.6	16.6	149	145	150	146
Zero till sowing without rice stubbles	19.4	16.4	19.8	16.8	152	146	153	148
Zero till sowing in standing rice stubbles	19.9	16.7	20.4	17.5	157	150	160	154
Zero till sowing after partial burning of rice stubbles	19.7	16.6	20.2	17.3	155	149	158	152
Bed Planting	19.6	16.6	20.0	17.1	154	148	156	150
C D (P=0.05)	0.6	0.4	0.6	0.5	5.2	3.8	5.6	4.4
Weed control treatments								
Clodinafop 60 g/ha	19.5	16.4	19.8	16.7	152	147	154	149
Clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha	19.6	16.6	20.0	17.0	154	148	155	150
Sulfosulfuron 25 g/ha	19.7	16.6	20.2	17.4	154	148	157	151
Mesosulfuron + iodosulfuron 12 g/ha	19.9	16.6	20.4	17.7	156	150	159	153
Control (unweeded)	19.1	16.2	19.4	16.5	151	145	152	147
C D (P=0.05)	0.4	0.3	0.4	0.4	2.8	2.4	2.9	2.6

bed planting treatments were statistically at par with each other and observed significantly higher available phosphorus conventional tillage during both years of study. Improvement in available phosphorus in soil was conspicuous where rice residues were retained at the time of sowing of wheat crop.

Regarding weed control treatments, at 0-15 cm soil layer, available phosphorus content was significantly higher in mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha than clodinafop 60 g/ha and unweeded control. Among all the weed control treatments, unweeded control observed the least available phosphorus content during both the years (Table 3). However, the variation among treatments was less at 15-30 cm soil depth as compared to 0-15 cm soil depth, whereas trend was same as that of 0-15 cm soil layer during both the years.

3.4 Available potassium

A thorough review of the data from Table 3, depicted that available potassium content in soil was again highest for both the soil depths (0-15 cm and 15-30 cm), during both the years under zero till sowing in standing rice stubbles, but this time closely followed by zero till sowing after partial burning of rice stubbles and lowest again with conventional tillage. Zero till sowing in standing rice stubbles and after partial burning of rice stubbles recorded significantly higher available potassium content in soil than conventional tillage treatment. Further, zero till sowing in standing rice stubbles recorded significantly higher potassium content than zero till sowing without rice stubbles at 0-15 cm soil depth for the first year and at both 0-15 cm and 15-30 cm soil depth for the second year. Zero till sowing of wheat without rice residues showed numerical improvement in available potassium over conventional tillage.

Different weed control treatments also significantly influenced available potassium content in soil during both the years at both the soil depths (Table 3). Mesosulfuron + iodosulfuron 12.0 g/ha showed the highest available potassium and the minimum values were observed in unweeded control treatment. Mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha recorded significantly higher available potassium content in soil than unweeded control. Further, mesosulfuron + iodosulfuron 12.0 g/ha showed significantly higher available potassium content than clodinafop 60 g/ha alone.

4 Discussion

4.1 Organic Carbon

Zero till sowing in standing rice stubbles resulted in higher soil organic carbon content in 0-15 cm and 15-30 cm soil layers than conventional tillage and bed planting during both growing seasons (Table 2). Higher soil organic carbon content in zero till plots with retention of rice stubbles might be due to addition of organic matter of rice stubbles, whereas, in conventional tillage plots, rice residues were removed which resulted in least organic matter in soil. Further, higher organic carbon content in zero till plots than conventional till and bed planting techniques might be due to less soil disturbance in zero till plots leading to lesser decomposition of crop residues. The results of the study are consistent with the results of Arshad et al. (1999), Das et al. (2003), Kumar and Yadav (2005), and Saikia et al. (2017).

Among the weed control treatments, herbicide treated plots showed improvement in soil organic carbon content than unweeded control plots during both the growing seasons at both the soil layers of 0-15 cm and 15-30 cm (Table 2). This might be due to higher root biomass of crop plants produced in the herbicide treated plots than unweeded plots.

4.2 Available Nitrogen

Zero till sowing in standing rice stubbles and after partial burning of stubbles showed positive trend in available nitrogen content in soil than conventional tillage at both the soil depths of 0-15 cm and 15-30 cm during both the years (Table 2). The higher available nitrogen content in zero till sowing with rice stubbles and partial burnt stubbles might be due to full or partial crop mass added which resulted in higher available nitrogen after decomposition of rice stubbles. Further, suppression of weeds in rice stubbles might have resulted in less nutrient uptake by weeds, resulting in more available nitrogen in soil. The findings are in agreement with the results of Das et al. (2003), Kharub et al. (2004), Kachroo et al. (2006) and Saikia et al. (2017).

Among the weed control treatments, all the herbicide treated plots viz., mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha, clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha and clodinafop 60 g/ha registered higher available nitrogen content in soil than unweeded control which recorded lowest available nitrogen during both the

year (Table 3). This lowest nitrogen content in unweeded control treatment might be due to more nitrogen uptake by weeds. Similarly, lower available nitrogen content with clodinafop 60 g/ha alone might be due to the reason that clodinafop only controls grass weeds not the broad leaf weeds resulting in more nutrient uptake by weeds as compared to other herbicide application treatments. Brar and Walia (2008) also reported higher total nitrogen uptake by crop + weeds in unweeded control than herbicide treated plots.

4.3 Available Phosphorus

The data presented in Table 3 showed higher available phosphorous in zero till sowing of wheat in standing stubbles as well as after partial burning than conventional tillage treatment during both the growing seasons at both the soil depths of 0-15 cm and 15-30 cm. Improvement in available phosphorus in soil was conspicuous where rice residues were retained at the time of sowing of wheat crop. Zero till sowing of wheat with retention of full or partial burnt stubbles added crop biomass, which might have resulted in higher phosphorus content in soil after decomposition of rice residues. Further, higher phosphorus content in zero till sown and bed planting treatments than conventional tillage treatment might be due to lower weed infestation resulting in lesser nutrient mining by weeds. The research findings are in agreement with the findings of Mishra (1984), Das et al. (2003), Kharub et al. (2004), Kachroo et al. (2006) and Saikia et al. (2017).

Regarding weed control treatments, the higher available phosphorus content in mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha, clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha and clodinafop 60 g/ha as compared to unweeded control at both the soil depths of 0-15 and 15-30 cm during both the growing seasons (Table 3) might be due to less total biomass (crop + weeds) production in herbicide application treatments resulting in lower cumulative phosphorus uptake by crop and weeds. However, as application of alone clodinafop 60 g/ha controls only grass weeds, thus resulting in more nutrient mining and ultimately lower available phosphorus content in soil. Brar and Walia (2008) also reported higher total phosphorus uptake by crop and weeds in unweeded control plots than herbicide treated plots.

4.4 Available potassium

Sowing of wheat under zero till condition in standing rice stubbles and after partial burning of rice stubbles showed higher available potassium content in soil than conventional tillage treatment without rice residues during both the year of experimentation at both 0-15 cm and 15-30 cm soil depth. Major part of the potassium uptake by rice plant remains in the rice residues after harvesting the rice grains. Higher potassium content in soil in the zero till sowing of wheat with full or partial burnt stubbles might be due to addition of crop residues. Zero till sowing of wheat without rice residues showed numerical improvement in available potassium over conventional tillage as zero till sowing of wheat favors lesser weed infestation as compared to conventional tillage. Das et al. (2003), Kharub et al. (2004) and Kachroo et al. (2006) also reported higher potassium content in soil where crop residues were added as compared to residue removal situations. Similarly, low available potassium content was also reported under conventional tillage system as compared to zero tillage treatment (Singh (1985); Matowo et al. (1999); Saikia et al. (2017)).

During both the years of experimentation, at both 0-15 cm and 15-30 cm soil depths, all the herbicide application treatments like mesosulfuron + iodosulfuron 12.0 g/ha, sulfosulfuron 25 g/ha, clodinafop 60 g/ha f.b. 2, 4-D 0.5 kg/ha and clodinafop 60 g/ha registered higher available potassium content in soil than unweeded control (Table 3), probably due to lesser potassium uptake by weeds. Alone clodinafop 60 g/ha resulted in lower potassium content in soil than other herbicide application treatments probably due to lesser weed control efficiency of clodinafop than other herbicides. Brar and Walia (2008) also reported lesser nutrient uptake by weeds in herbicide application plots than untreated plot.

5 Conclusion

In the present study, analysis of soil samples taken after the harvest of wheat crop from both 0-15 cm and 15-30 cm soil depths indicated that zero till sowing of wheat in standing rice stubbles found significantly higher organic carbon, available nitrogen, phosphorus and potassium in soil than conventional till sown wheat after the removal of rice residues. Partial burning of rice stubbles also showed

improvement in organic carbon, available nitrogen and potassium in soil but response was less pronounced than rice stubbles without burning. Furthermore, simply zero till plots showed positive trend in organic carbon and available nitrogen, phosphorus and potassium in soil. Different herbicide application treatments although did not exhibit any difference in soil organic carbon, but significantly improved the available nitrogen, phosphorus and potassium level in soil by reducing nutrient mining by weeds than untreated control.

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