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T Pandiaraj
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

AK Bhardwaj
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Sumit Chaturvedi
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Correspondence
T Pandiaraj
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Tillage, mulching and fertility effects on vegetable pea production under conservation agriculture after rice cultivation in Indo-gangetic plains

T Pandiaraj, AK Bhardwaj and Sumit Chaturvedi

Abstract
The rice–wheat covering 13.5 million hectare in the Indo-Gangetic Plains is key cropping system for food security. Its sustainability is at threat as the existing cultivation practices are inadequate resulting in low factor productivity and ecological unsafe. This study was designed to improve system growth and productivity of vegetable pea with responses to a combination of different tillage, mulching and fertility levels. The results revealed that plant height of vegetable pea was 7% more in conventional tillage than reduced tillage system. However, reduced tillage had achieved earlier growth period with response to 75% flowering and podding in vegetable pea as compared to conventional tillage system. Mulching with paddy straw had recorded positive growth than no mulch system. Similarly, fertilize with 100% RDF was found to higher growth parameters and achieved earlier 75% flowering and podding. Compared to conventional tillage method, reduced tillage gave 25% higher pod yield. Pod yield under mulching practices was very high (57% more) than no mulch. The 100% RDF was found to be 17% more pod yield than 75% RDF. The similar responses were also observed for root characteristics. In the conventional tillage, root length observed higher than reduced tillage. However, root dry weight and root nodules were recorded more with reduced tillage. Similarly, paddy straw mulch and 100% RDF gave more root characteristics in vegetable pea. Hence, conservation agriculture technologies can be more efficient and productive towards higher productivity, profitability and resource conservation; however, long term studies in diverse soil, climatic and socio-economic conditions still require to be conducted to validate the observations made in the reported study.

Keywords: Conservation agriculture, Mulching, Pod yield, Roots, Reduced tillage, RDF

Introduction
Vegetable pea (*Pisum sativum* L.) is an important nutritional value crop for human and animal consumption. It is well thrived to its soil and climatic conditions. The vegetable pea varieties are extensively grown in both gardens and for field production. Production of world vegetable (green) pea keeps growing progressively increasing 15.5 million tons in 2013, the main producer being China (FAO 2015) [7]. According to Indian Council of Agriculture Research (ICAR) 2013, the national average acreage, production and productivity of vegetable pea were 0.37 m.ha, 3.57 m.t. and 9.7t/ha, respectively.

During the Green Revolution, the widespread adoption of high-yielding cereals along with improved crop management practices and availability of irrigation water and chemical inputs have led to a remarkable increase in system productivity. But evidence now appears that the productivity is plateauing and total factor productivity is declining because of a fatigued natural resource base and therefore, sustainability of this cropping system is at risk (Ladha *et al.*, 2003) [12].

In this situation, the adoption of legumes such vegetable pea into rice-based cropping systems, offers opportunities to increase and sustain productivity and income of small rice farmers in North and Central India. Vegetable pea is generally grown in rotation of rice-rice-legume or rice-legume-legume with two or more irrigations during the season. Although vegetable pea grown as a secondary crop after rice are normally not fertilized in the India, potential yield increases due to the additional fertilizer application are possible if residual fertilizer from the rice phase is inadequate. Rice is grown best under puddled, reduced and anaerobic soil conditions; whereas vegetable pea requires un-puddled, aerobic and oxidized soil conditions. The two conditions are related to large differences in physical, chemical and biological properties of the soil. The puddled conditions of the soil are a major cause of the poor establishment and performance of secondary crops after rice (Syarifuddin, 1979; Sumarno *et al.*, 1988) [21]. As the puddled layer dries out, soil strength increases rapidly. Hence, crop establishment, root proliferation and growth performance of vegetable pea through the puddled and compacted layers becomes increasingly more difficult. Although tillage can potentially be used to improve soil physical conditions, it is expensive, time consuming and often wasteful in terms of residual moisture. Reduced tillage such zero tillage, minimum tillage could therefore be beneficial (Syarifuddin, 1982) [22]. Reduced tillage either a manual or animal powered system or mulching are offering a viable opportunity to increase crop productivity in a long term sustainable manner (Wall, 2009; Thierfelder and Wall, 2010) [27, 23]. The reduced tillage techniques that have been developed include clean and mulch ripping, no-till tied ridging and zero tillage (Twomlow and Bruneau, 2000) [26]. The soil water and crop yield benefits derived from using reduced tillage can be enhanced by using mulch cover in the cropping system. For the post rice growing soils, mulching may be a suitable agronomic practice for conserving soil and water and controlling soil temperature regimes (Chakraborty *et al*., 2008) [4]. Soil biota increase in a mulched soil environment, thereby improving nutrient cycling and organic matter builds up over a period of several years (Holland, 2004) [9].

Further, under unfavorable conditions, such as too wet, too dry or excessively high temperatures, seedlings become prone to damage by leaf hopper and flea beetles. These constraints indicate that early sowing and reduced tillage systems along with mulching appear to be more reliable than conventional tillage systems (Suyamto *et al*., 1989) [20]. It is possible to use tillage, fertilizers and mulch to improve the management of the soil and widen the window of opportunity for sowing vegetable pea. Therefore a field study was undertaken with an aim to determine the effect of resource conservation through agronomic management practices on the growth and yield performance of vegetable pea crops grown after rice.

Materials and methods

Location, Climate and Soil

The experiment was established at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India in 2011-12 and 2012-13 under irrigated conditions. The experiment site is situated at latitude of 29º N and longitude of 79.3º E at an elevation of 243.8 m above mean sea level. The soil was sandy loam in texture having a pH (7.2), EC (0.14), organic carbon (0.70%), available nitrogen (196.4 kg/ha), available phosphorous (21.57 kg/ha) and available potassium (169.2 kg/ha). During the experimental period the average rainfall in 2011-12 and 2012-13 was 2750 and 2518 mm, respectively was recorded.

Treatment and design

The treatments consisted of two tillage (reduced tillage, RT; conventional tillage, CT) and two levels of mulching (no mulch, M_0 and paddy straw mulch, M_1) in main plots and two level of fertility (100% RFD, F_1 and 75% RFD, F_2) in sub-plot. The experimental design was a factorial split plot with three replications. Each experimental unit consisted of 6.0 m × 3.6 m (21.6 m^2) plot. The tillage methods under reduced tillage were direct seeding for rice crop without puddling the soil and reduced tillage for vegetable pea whereas under conventional tillage were conventional tilled (puddled) transplanted rice, and conventional tilled up to soil get fine pulverized. After rice harvesting, a portion of rice straw (4000-4500 kg ha^{-1}) was left as mulch on the soil surface, instead of removal or burning of straw (usually practiced by farmers). This straw was chopped into small pieces and applied between the inter rows of vegetable pea.

Cultivation details

Prior to sowing of vegetable pea, rice cultivar PR-113 was planted at seed rate 40 kg ha^{-1} for transplanting and 60 kg ha^{-1} for direct seeding in the main field on first fortnight June in 2011 and 2012. So after harvested rice crop, the field was prepared according to tillage treatments difference. Vegetable pea cultivar Arkel was sown throught the experiment in all the treatment plots at a seed rate of 100 kg ha^{-1}. Row and plant spacing was 30×10 cm adopted in all the treatments. Fertilizers were applied as basal dose prior to seeding at rates of 20-40-40 kg NPK for the treatment F_1 and 15-30-30 kg NPK per hectare for F_2 treatment through the source of 10-26-26 NPK complex and urea. During the experimental period, weeds were controlled by herbicide pendimethalin at the rate 1.0 kg *a.i.* per hectare.

Statistical analysis

Statistical analysis was conducted using ANOVA procedures. The Duncan Multiple range test was used to compare treatment means of yield parameters.

Results and discussion

Growth character

Growth characters of vegetable pea including plant height, days taken to 75% flowering and 75% podding were differently affected by tillage, mulching and fertility levels (Table 1).

In both the years, tillage methods had a significant effect on vegetable pea plant height. The highest average plant height (51.0 cm) was recorded with conventional tillage, which showed statistical disparity with reduced tillage (47.6 cm) and these treatments proved 7.0 percentages higher to the reduced tillage treatment. Among the mulching treatments, paddy straw mulch significantly improved 22.8 percentages higher plant height (54.3 cm) as compared to plant height had recorded in no mulch treatment (44.2 cm). Similarly, plant height was 4.3 percentages higher in 100% RDF application than 75%RDF application. During the first year, two way interactions between mulch × fertility and three way interaction responses to tillage × mulch × fertility had statistically significant effect on plant height of vegetable pea. During the study observed the crop growth rate was higher in the mulched plots with 100% RDF under CT practices in all the growth stages of Veg. Pea. The higher value of crop growth associated with this treatment might be due to higher root growth, more number of nodules. The same results were also reported by (Fabrizzi *et al*., 2005) [6].

Table 1: Plant height (cm), Days taken to 75% flowering and Days to 75% physiological maturity of vegetable pea as influenced by different RCT, s practices after rice cultivation.

Treatments		**Plant height**		**Days taken to 75% flowering**		**Days to 75% podding**	
		2011-12	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Tillage system (T)							
Reduced tillage (RT)		47.6	49.4	35.5	36.0	58.5	59.0
Conventional tillage (CT)		51.0	51.8	38.3	38.6	61.5	62.6
SEm.±		*0.33*	*0.33*	*0.32*	*0.24*	*0.51*	*0.38*
LSD (P=0.05)		*1.13*	*1.13*	*1.10*	*0.84*	*1.76*	*1.30*
Mulch (M)							
No- mulch		44.2	47.3	37.7	37.8	60.6	61.6
Straw mulch		54.3	53.9	36.2	36.7	59.4	60.0
SEm.±		*0.33*	*0.33*	*0.32*	*0.24*	*0.51*	*0.38*
LSD (P=0.05)		*1.13*	*1.13*	*1.10*	*0.84*	*NS*	*1.30*
Fertility levels (F)							
100% RDF		50.3	52.2	36.4	36.2	59.4	60.1
75% RDF		48.2	49.0	37.4	38.3	60.6	61.5
SEm.±		*0.37*	*0.45*	*0.28*	*0.23*	*0.61*	*0.37*
LSD (P=0.05)		*1.21*	*1.47*	*0.92*	*0.74*	*NS*	*1.19*
Interaction effect between different treatments							
T x M	SEm.±	0.45	0.46	0.45	0.35	0.72	0.53
	LSD (P=0.05)	NS	NS	NS	NS	NS	NS
T x F	SEm.±	0.53	0.64	0.40	0.32	0.87	0.52
	LSD (P=0.05)	NS	NS	NS	NS	NS	NS
M x F	SEm.±	0.53	0.64	0.40	0.32	0.87	0.52
	LSD (P=0.05)	1.71	NS	NS	1.05	NS	NS
T x M x F	SEm.±	0.74	0.90	0.56	0.46	1.23	0.73
	LSD (P=0.05)	2.42	NS	NS	NS	NS	NS

The plant grown in a conventional tillage field had favourable environment for the formation of more number of nodules and better root growth, thus resulted in achieving a higher plant growth rate. The Rice straw mulching significantly suppressed weed growth. Soil moisture determining the germination and establishment of vegetable pea seedlings was also conserved well in mulch. Mulch helps maintain optimum soil moisture, aids seed establishment and promotes excellent crop growth throughout the season. All these are positive productivity indicators. Therefore, by controlling the limiting factors, straw mulching can enhance the crop growth and development (Sharma and Acharya, 2000) [16]. The shoot height positively correlated with increasing N rate. This result was also corroborated with the same state that higher shoot height was noticed with 100% RDF under mulch treatment.

In both the years, days taken to 75 % flowering and podding are statistically significant. Days taken to 75% flowering and podding tended to be earlier at reduced tillage. The earlier 75% flowering and podding were obtained under paddy straw mulching treatments. Likewise, 100% RDF treatment had a significant effect on earlier flowering and podding of vegetable pea. However, mulching and fertility had no significant effect on 75% podding in the first year. Though reduced tillage recorded lower plant height, same treatments could result in achieves earlier 75% flowering and podding. This result may be attributed that wider spatial and temporal variation in average soil temperature was obtained under CT than under RT concurrently; higher soil temperature in RT during *rabi* season at all the depth of soil had resulted in accelerated the growth and earlier flowering and podding. In a field experiment, Toshitsugu and Haruhiko (2002) [25] were also corroborated the same results in reduced tillage. Earlier studies showed that the surface soil temperature under mulch during the growth period improved by 2–6.8◦C, as compared with no mulch (Cai and Wang, 2002) [3], having a very strong influence on growth period, thus causing decreased life cycle of crop.

Pod yield of Vegetable pea

Tillage, mulching and fertility interaction had significant influence vegetable pea pod yield recorded at the end of 2011 and 2012 season (Fig. 1). The three way interaction had a significant effect on pod yield of vegetable pea. The vegetable pea pod yields increased in 100% RDF application along with mulch cover in the reduced tillage. This suggests that biomass built up under the different resource conservation techniques could be translocated into pod yield. Further, the vegetable pea pod yield in 75% RDF with mulch cover in reduced tillage was higher than though 100% RDF applied along with mulch application in conventional tillage system. So, the reduced tillage systems gave more pod yield compared to the conventional systems in both years regardless of the mulch and fertilizer. No mulch cover in reduced tillage practices, 75% RDF application produced pod yield was statistically at par with the treatment of same dose of fertilizer application with paddy straw mulch cover in conventional tillage systems. Similarly, no mulch and 100% RDF under reduced tillage produced pod yield was statistically did not vary the result of pod yield in mulch cover with 75% RDF application in conventional tillage system. From above the results obviously showed that farmers could save one-fourth cost of fertilizer application to vegetable pea production under resource conservation techniques. Farmers using resource conservation techniques such reduced tillage and mulch on the vegetable pea production after rice stand a better chance of getting higher crop yields and market choice compared to farmers using the traditional system.

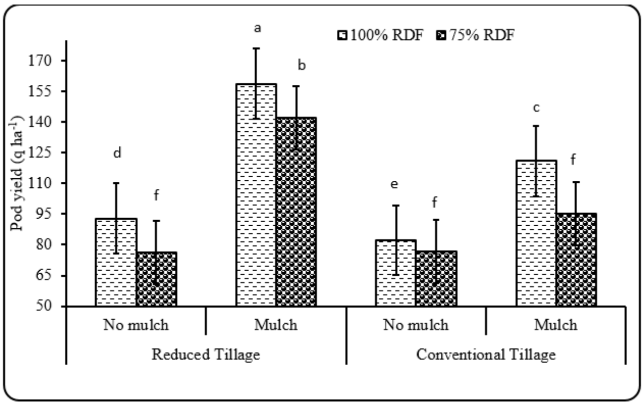

Fig 1: Interaction effects of tillage × mulch × fertility on pod yield (q ha^{-1}) of vegetable pea after rice cultivation. Error bars represent standard error. Treatments means followed by common letter (s) are not significantly different among each other by DMRT at P = 0.05 level of significance.

During the experimental period, conservation tillage resulted in enhanced rainwater infiltration and more water storage during kharif rice crop in the rainy season before sowing of vegetable pea crop. Due to this, reduced tillage and mulch through paddy straw application gave a yield around 25% and 57% higher in vegetable pea, respectively. Fertilize with 100% RDF application increases 17% higher pod yield compared to 75% RDF. Mulch application combined with reduced tillage methods had an additional positive effect on pod yields. These findings are supported by those of Shirani *et al*. (2002) [17] and Albuquerque *et al.* (2001) [1] who reported that height of plant, the number of green leaves, number of grains per ear and grain weight were higher in conservation tillage and mulch application. Tolk *et al.* (1999) [24] observed that mulches applied to soil increased yield significantly as compare with bare soil. These results are also in agreement with those of Sarkar and Singh (2007) [14] and Baudron *et al*. (2015) [2] who concluded that mulching reduces leaching of nutrients, reduced weed problems, reduced evaporation of soil water and increased water use efficiency. They also concluded that mulch helped maintain optimum soil moisture and promoted excellent crop growth throughout the growing season. Reduced tillage in combination with mulching significantly increased rooting density and yield of crop as compared to that in CT and no-mulching (farmers' practice) (Hobbs and Govaerts, 2010) [8]. This conservation technique provides scope for synergy. The same is true for the interaction between mulching and fertilizer application. Fertilizer application in barren soil could cause loss through various ways like leaching, volatilization, erosion along with soil and uptake by weeds; but applied in mulch covered soils resulting in check the above losses and improved overall efficiency of fertilizer use in the long term with a significant reduction in the fertilizer requirements to maintain the production and soil nutrient levels (Saturnino and Landers, 2002) [15].

Root characteristics

In comparison to the reduced tillage, conventional tillage treatments significantly increased the total root length in both study years (Table 2). However, root dry weight and number of root nodules were significantly higher in the reduced tillage treatments. Root length was clearly related to soil strength and depth. In the present investigation observed the roots in conventional tillage system extended and penetrated to deeper soil depth because intensive tillage operations loosened the soil layer. However, the tillage hardpans formed at the depth about 30-45 cm soil layer in conventional tillage system, which greatly restricted root penetration. Due to this, only root length was extended up to certain soil layer; after which root length hampered. Whereas, root has been often greater in the top soil under reduced tillage system due to the greater availability of water and nutrients. Even though reduced tillage had been recorded lower root length, most of the root biomass, lateral branches of roots and root nodules were observed under the soil surface due to compaction in soil beneath as compared to conventional tillage. This result was also agreed with those of Das, 2009 who reported that more root biomass was observed near the soil surface as compared to conventionally tilled soils and he also stated that conservation tilled soil facilitated more number of nodules in greengram crop. The mulching influenced more significantly than tillage practices because mulching levels influenced 24 per cent than 9 per cent in case of tillage practices. Compared to the no mulch, straw mulching significantly increased the root length, root dry weight and number of nodules in both years. The paddy straw mulch treatment displayed greater effect on root characteristics of vegetable pea. This was due to better availability of water and aeration near the root; this encourages the plant for developing a stronger root system in mulching plot (Khurshid *et al*., 2006) [11].

Table 2: Root characteristics of vegetable pea as influenced by different RCT, s practices after rice cultivation.

Treatments		Root length (cm)		Root dry weight (g plant-^{1})		No. of nodules plant-^{1}	
		2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Tillage system (T)							
Reduced tillage (RT)		29.5	31.3	1.01	1.11	19.2	17.3
Conventional tillage (CT)		33.3	34.2	0.92	1.07	17.4	17.6
SEm.±		*0.24*	*0.27*	*0.009*	*0.006*	*0.10*	*0.17*
LSD (P=0.05)		*0.83*	*0.93*	*0.030*	*0.021*	*0.35*	*NS*
Mulch (M)							
No- mulch		28.6	29.2	0.93	1.00	17.1	16.0
Straw mulch		34.1	36.3	1.00	1.19	19.4	18.9
SEm.±		*0.24*	*0.27*	*0.009*	*0.006*	*0.10*	*0.17*
LSD (P=0.05)		*0.83*	*0.93*	*0.030*	*0.021*	*0.35*	*0.37*
Fertility levels (F)							
100% RDF		32.4	33.5	0.98	1.14	19.0	17.9
75% RDF		30.4	32.1	0.95	1.04	17.5	17.0
SEm.±		*0.25*	*0.21*	*0.007*	*0.009*	*0.10*	*0.16*
LSD (P=0.05)		*0.81*	*0.67*	*0.023*	*0.030*	*0.34*	*0.53*
Interaction effect between different treatments							
T x M	SEm.±	0.34	0.38	0.012	0.009	0.14	0.15

	LSD (P=0.05)	NS	1.32	NS	NS	0.49	NS
T x F	SEm.± LSD (P=0.05)	0.35 NS	0.29 0.95	0.010 NS	0.013 NS	0.15 NS	0.23 NS
M x F	SEm.± LSD (P=0.05)	0.35 NS	0.29 NS	0.010 NS	0.013 0.042	0.15 NS	0.23 NS
T x M x F	SEm.± LSD (P=0.05)	0.50 NS	0.41 NS	0.014 NS	0.018 NS	0.21 0.68	0.33 NS

The use of mulches not only improved the bulk density, but also reduced the compaction of soil that might have enhanced the aeration and microbial activities in the soil, thus resulting to increased root penetration, root biomass, root nodules and cumulative feeding. The findings on root parameters are in line with the observations of Mbah *et al*. (2010) [13]. Fertility treatments had significant effects on root length, dry weight and number of nodules per plant. In both years, root characteristics, i.e. at 100% RDF application was significantly increased as compared to 75% RDF application. This might be due to the addition of full doses of N, P and K applied along with paddy straw residue as mulch might have helped in the formation and growth of roots during crop growth stages. Similar points were also confirmed by results of Subbulakshmi *et al*., (2009) [18].

Conclusion
The results of this study concluded that the conservation agriculture technologies i.e. reduced tillage, mulching with appropriate dose of fertilizer could be improved the vegetable pea production. Combined application of reduced tillage and mulching along with 100% RDF showed positive response with yield. Similarly, reduced tillage, paddy straw mulch and 100% RDF application had increased vegetative growth and root characteristics of vegetable pea as compared to conventional practices in the experiment. Hence, this study clearly suggested that vegetable pea can be recommended as alternate crop for existing wheat after rice and conservation agriculture technologies could be better option for not only higher productivity but also cost effective and ecological safe.

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