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Full Research Article

Root Growth and Productivity of Wheat, Chickpea and Potato as Influenced by Nutrient Management Practices

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Abstract

Field experiments were conducted during *rabi* / winter (November–March) seasons of 2011-12 and 2012-13 at research farm of Indian Agricultural Research Institute, New Delhi to evaluate the root growth and performance of wheat, chickpea and potato grown in different soybean-based cropping systems with 5 nutrient management practices. The results revealed that root growth in terms of root length, root volume and root dry weight of wheat and chickpea were observed significantly maximum where 50% RDN was substituted with FYM along with 50% RDF. Whereas, all the root parameters of potato were higher with the fertilization of 100% RDF. All the yield parameters and yields of wheat in soybean-wheat-fallow and soybean-wheat-mungbean cropping system did not differ significantly. All the yield parameters viz., effective tillers m^{-2}, length of $spike^{-1}$, grains spike and 1000-grain weight as well grain and stover yields of wheat were highest with the application of 100% RDF during both the years. Similarly, the maximum values of yield attributes and tuber and haulms yields of potato were recorded with the 100% RDF during both the years. However, no significant variation among all sources of nutrient was noticed during 2011-12 and among 100% RDF and substitution of 50% RDN through FYM during 2012-13 in both the crops. Whereas, significantly maximum yield contributing parameters and grain and stover yields of chickpea were found in the treatment receiving 50% RDF+50% RDN through FYM followed by 25% RDF+50% RDN through FYM+ biofertilizers during both the years.

1. Introduction

In India wheat [*Triticum aestivum* (L.) emend. Fiori and Paol.] and chickpea (*Cicer arietinum* L.) are the most important crops generally grown after soybean [*Glycine max* (L.) Merr.]. Soybean-wheat followed by soybean-chickpea has been recognised as the most remunerative soybean-based cropping system in central part of the country (Vyas et al., 2008). Presently, emphasis has been given to find feasibility of soybean in north-western region of India during *rainy* season. This also needs to indentify the suitable crops for winter and/or summer season for maximum productivity of the system. Inclusion of short duration crop like potato (*Solanum tuberosum* L.), vegetable or legumes in existing system may ameliorate soil fertility and break the cycle of weed and disease complex as against continuous cropping and at the same time, provides opportunity to grow suitable crop during summer season. Potato can be fitted suitably into different cropping system to increase the efficiency of time and resources (Sharma et al., 2006). Studies have shown that potato-based cropping systems are usually more profitable than cereal-based cropping systems (Pandey et al., 2008). Growing of crops of diverse nature also needed to break the monotony of the system (Tripathi and Singh, 2008).

The application of heavy doses of chemical fertilizers enhanced the productivity of the crops on one end but on the other, continuous application of chemical fertilizers deteriorates soil health, leading to declining productivity of the soil. The success of any cropping system depends upon the appropriate management of resources including balanced use of manures and fertilizers. Integrated use of fertilizers, organic manure and biofertilizers along with residual fertility plays important role in maintaining soil health as well asraising productivity of the system in long run (Behera et al., 2007; Chitale et al., 2013). Root study has been given least importance due to under ground habitat and inherent difficulty in studying them. The growth of the plant roots is governed by the cultivation practices, soil properties and nutrient dynamics in the soil and better root growth is related to better rhizosphere environment which ensures a steady supply of water and nutrients to the crop plants and helps in realising the productivity potential of the crops (Yadav et al., 2008; Aggarwal et al., 2006). Integrated nutrient management enhances the nutrients availability in soil as well as improves soil condition congenial for better root growth (Meena et al., 2013). Therefore, the better growth of the crop in terms of above ground biomass could also be correlated with improved below ground biomass i.e. root growth. Therefore, present study was planned to evaluate the effect of different levels of nutrient management on root growth and performance of wheat, chickpea and potato grown in soybean-based crop sequences.

2. Materials and Methods

Field experiments were conducted during winter (*rabi*) seasons of 2011-12 and 2012-13 at the research farm of Indian Agricultural Research Institute, New Delhi, India, situated at a latitude of 28°38´ N, longitude of 71°09´ E, and altitude of 228.6 m above the mean sea level (Arabian sea). The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July–September) with mean annual evaporation of 850 mm. The soil of the experimental site was sandy clay loam in texture (sand 63.8%, silt 12.2% and clay 24.0%) with pH 7.9, cation exchange capacity 10.5 c mol kg^{-1} and EC 0.34 dS m^{-1} in the top 15 cm of soil. The soil was low in available nitrogen (157.0 kg ha^{-1}) and organic carbon (0.42%), medium in available phosphorus (14.2 kg ha^{-1}) and potassium (240 kg ha^{-1}). The treatments comprised of 4 cropping systems [soybean-wheat-fallow (CS_1), soybean-wheat-mungbean (CS_2), soybean-chickpea-fodder sorghum (CS_3) and soybean-potato-mungbean (CS_4)] and 5 nutrient management practices viz., control (NM_0), 100% RDF (NM_1), 50% RDF+50% RDN through FYM (NM_2), 50% RDF+25% RDN through FYM+biofertilizers (NM_3) and 25% RDF+50% RDN through FYM+biofertilizers (NM_4). The experiment was laid out in strip plot design and replicated thrice. The experiment was initiated from soybean in *kharif* / *rainy* (July to October) season of July 2011. Wheat 'HD 2967', potato '*Kufri Badshah*', chickpea '*Pusa* 1103' were taken for experiment during winter (November to March) season in respective cropping systems. The recommended dose of fertilizers (RDF) for wheat (158:76:47 of $N:P_2O_5:K_2O$ kg ha^{-1}) and chickpea (44:27:3 of $N:P_2O_5:K_2O$ kg ha^{-1})was calculated based on soil test crop response (STCR) equations (Sharma and Singh, 2007) for the experimental farm taking initial soil test values of available N, P and K at the beginning of the experiment and targeted yields of crops as 5.0 and 2.0 t ha^{-1}, respectively. The RDF for potato (150:60:80 of $N:P_2O_5:K_2O$ kg ha^{-1}) wastaken based on recommended rates as STCR equations were not available for experimental location. The FYM was applied before sowing/planting of crops based on the nitrogen equivalent basis and nutrient requirement of each crop in respective treatment. The FYM consisted 0.59 and 0.58% N, 0.29 and 0.29% P, and 0.54 and 0.56% K, respectively during 2011-12 and 2012-13. The fertilizers and FYM were applied as per recommended methods and time of application for each crop. Seeds/tubers of crops were treated with Rhizobium/ Azotobacter and PSB according to treatments.

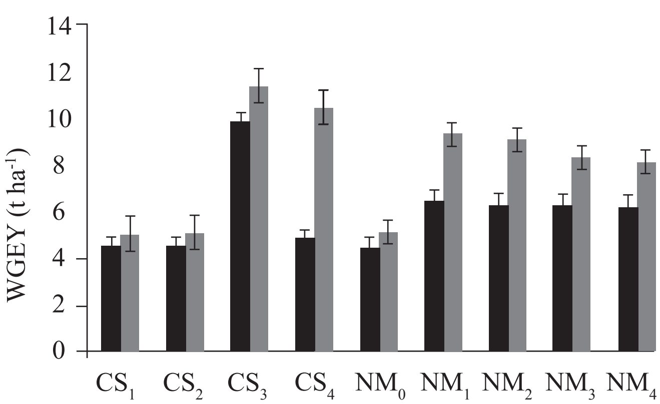


Figure 1: Effect of cropping system and nutrient management on wheat grain equivalent yield of crops. Error bars indicates LSD (p=0.05) values

After harvesting of soybean, the wheat, chickpea and potato were sown in the first week of November. All the crops were grown with recommended package of practices. For studying the yield attributing parameters of crops, five plants were tagged randomly in second row of either side in the net plot. For root studies, root samples were taken from third row of the crop at 50% flowering stage with a root auger of 8.0 cm diameter and 15 cm height (core volume=754.28 cm^3) to take root samples up to 0–15 cm depth of soil profile. The core ring was kept at the base of the stem at the centre. The root samples taken from each plot were washed in water to remove soil. Then, the roots were air-dried so as to make the root samples ready for scanning. The measured root parameters like root length and root volume were recorded through scanning and image analysis using RHIZO system, operated in a computer mounted with the scanner of RHIZO system. After scanning the root samples were dried at 60 °C for 48 hrs for recording root dry weight. Yield of all the crops was recorded from the net area harvested and converted to t ha^{-1}. Economic yields of the crops were converted to wheat grain equivalent yield (WGEY) for comparing the productivity, taking into account the market prices of the crops. Statistical analysis of the data was carried out using standard analysis of variance (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Root growth of crops

The root growth studied in terms of root length, root volume and root dry weight of different crops at 50% flowering/45 DAP (potato) stage influenced significantly with the nutrient management. All the root parameters were found better with combined application of nutrient sources in wheat (Table 4) and chickpea (Table 5). The application of 50% RDF+50% RDN through FYM registered highest values of root parameters in wheat and chickpea. This might be because the conjunctive use of nutrients comprised of both readily (fertilizers) and slow-release (FYM) sources of nutrients which play an important role in improving the root biomass (Sharma et al., 2008). The higher values of root parameters under inorganic+organic treatments might also attributed to better nutrient supply and creation of better physical environment by way of lowering of bulk density and penetration resistance in the presence of organic manure. Converse to above crops, the highest values of root parameters of potato recorded with the application of 100% RDF (Table 5). The potato was planted on ridges and the crop might have faced lesser resistance to grow on the ridges and the better availability of nutrients under 100% RDF resulted in better root growth. The higher values of root parameters also found to be positively correlated with yields of the crops under respective treatments (Figure 2 a to i).

3.2. Wheat yield

Yield attributes and yields of wheat under soybean-wheat-fallow and soybean-wheat-mungbean systems did not vary significantly during both the years, however relatively higher values were recorded in soybean-wheat-mungbean than soybean-wheat-fallow system during 2012–13 (Table 1). Among the different nutrient sources, application of 100% RDF recorded significantly highest number of effective tillersm^{-2}, length of spike, grains spike^{-1} and 1000-grain weight as compared to control (Table 1). All other nutrient sources found at par with 100% RDF with regard to all above yield attributes. The application of 50% RDF+50% RDN through FYM and 25% RDF+50% RDN through FYM+biofertilizers were found significantly superior over control in affecting the yield attributes of wheat duringboth the years. Probably due to more absorption and utilization of available nutrients under inorganic sources, leading to overall improvement of crop growth with improvedsource-sink relationship (Uwah

Table 1: Effect of cropping systems and nutrient management on yield attributes and yield of wheat

Treatment	Effective tillers m^{-2}		Length of spike (cm)		Grains spike^{-1}		1000-grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Cropping systems												
Soybean–wheat–fallow	362	364	10.1	10.1	45.3	45.5	44.24	44.66	4.50	4.97	5.32	5.87
Soybean–wheat–mungbean	359	376	10.0	10.2	44.0	48.4	44.96	45.52	4.49	5.08	5.32	5.97
SEm±	3.5	3.3	0.06	0.06	0.43	0.39	0.356	0.220	0.060	0.08	0.071	0.123
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
Control	342	344	9.7	9.8	41.1	42.1	43.10	43.35	3.43	3.53	4.18	4.29
100% RDF	378	387	10.3	10.4	47.1	49.9	45.95	46.55	4.91	5.67	5.76	6.62
50% RDF+50% RDN-FYM	365	383	10.2	10.4	45.5	49.0	43.70	46.15	4.76	5.55	5.57	6.48
50% RDF+25% RDN-FYM+biofertilizers	362	371	10.2	10.3	45.1	47.4	45.20	44.75	4.72	5.40	5.55	6.33
25% RDF+50% RDN-FYM+biofertilizers	358	367	10.1	10.2	44.5	46.3	45.05	44.65	4.68	5.00	5.54	5.89
SEm±	9.2	7.0	0.10	0.13	1.03	1.14	0.486	0.650	0.116	0.077	0.136	0.139
LSD (p=0.05)	30.0	22.8	0.33	0.42	3.36	3.73	1.585	2.120	0.377	0.250	0.445	0.452
SEm±	9.2	7.0	0.10	0.13	1.03	1.14	0.486	0.650	0.116	0.077	0.136	0.139
LSD (p=0.05)	30.0	22.8	0.33	0.42	3.36	3.73	1.585	2.120	0.377	0.250	0.445	0.452

Table 2: Effect of nutrient management on yield attributes of chickpea

Treatment	Pods plant^{-1}		Gains pod^{-1}		100-grain weight (g)		Grain yield (t ha^{-1})		Stover yield (t ha^{-1})	
	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13
Control	38.2	39.5	1.2	1.2	19.02	19.20	1.52	1.82	2.95	3.54
100% RDF	50.4	50.4	1.3	1.4	21.20	21.32	1.87	2.10	3.43	3.85
50% RDF+50% RDN-FYM	53.0	55.1	1.4	1.5	21.83	21.80	1.95	2.35	3.54	4.29
50% RDF+25% RDN-FYM biofertilizers	48.3	48.3	1.3	1.3	21.00	21.11	1.75	2.05	3.25	3.81
25% RDF+50% RDN-FYM+ biofertilizers	50.2	53.2	1.3	1.4	21.20	21.33	1.82	2.26	3.35	4.16
SEm±	1.61	1.14	0.04	0.03	0.841	0.768	0.061	0.081	0.112	0.133
LSD (p=0.05)	5.24	3.73	NS	NS	NS	NS	0.198	0.264	0.366	0.435

et al., 2011), which in turn enhanced the yield attributes of wheat during both the years.

Wheat grain and straw yields were significantly higher under the application of 100% RDF followed by 50% RDF+50% RDN through FYM during both the years of study. The application of 100% RDF registered an increase of 43.15 and 60.62% higher grain yield over control during 2011-12 and 2012-13, respectively (Table 1). Similarly, application of 50% RDF+ 50% RDN through FYM also increased the grain yield of wheat to the tune of 38.78 and 57.22% over control during 2011-12 and 2012-13, respectively. The different nutrient sources could not brought any marked variation in harvest index of wheat during both the years. Substitution of RDF with organic manure or biofertilizers was found insufficient to achieve potential yield during both the years. However during 2012-13, only marginal difference was observed between 100% RDF and substitution of 50% RDN through FYM, which might be due to residual effect of FYM applied to previous crops. Stimulated vegetative growthof wheat on account of adequate and prolonged supply ofprimary nutrients in treatments receiving 100% RDF manifested itself in increased number of effective tillers, grains spike^{-1} and test weight. Similar findings were also reported by Behera et al. (2007) in wheat. Higher yield attributes with 100% RDF arethus responsible for increased yields.

3.3. Chickpea yield

Among the yield attributes of chickpea, only pods plant^{-1} varied significantly with the application of nutrient sources (Table 2). Significantly maximum pods plant^{-1} were recorded with the application of 50% RDF+50% RDN through FYM over control

Table 3: Effect of nutrient management on yield attributes of potato

Treatment	Number of potato hill^{-1}		Fresh weight of potato (g hill^{-1})		Dry weight of potato (g hill^{-1})		Tuber yield (t ha^{-1})		Haulm yield (t ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Control	7.6	8.5	130.5	255.0	17.7	36.2	8.73	16.52	0.73	1.67
100% RDF	12.1	14.2	225.6	426.3	34.7	67.3	15.17	38.84	1.23	3.72
50% RDF+50% RDN-FYM	11.3	14.0	201.7	419.8	31.3	65.9	15.07	37.09	1.15	3.45
50% RDF+25% RDN-FYM+ biofertilizers	10.2	12.9	180.3	387.5	27.0	58.8	15.04	30.72	1.12	2.71
25% RDF+50% RDN-FYM+ biofertilizers	9.8	13.4	175.8	402.7	26.4	61.9	14.66	33.29	1.07	2.86
SEm±	0.57	0.76	5.62	14.29	0.79	2.00	0.435	1.140	0.034	0.109
LSD (p=0.05)	1.86	2.47	18.32	46.62	2.59	6.52	1.418	3.716	0.112	0.356

Table 4: Effect of nutrient management on root parameters of wheat

Treatment	Root length (cm)		Root volume (cm^3)		Root dry weight (mg $plant^{-1}$)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Control	160.7	161.4	3.38	3.45	265	296
100% RDF	181.3	188.1	4.53	4.75	340	357
50% RDF+50% RDN-FYM	187.7	195.6	4.57	5.15	415	366
50% RDF+ 25% RDN-FYM+ biofertilizers	177.9	180.2	4.36	4.70	330	363
25% RDF+50% RDN-FYM+ biofertilizers	176.7	185.1	4.21	4.75	315	365
SEm±	5.00	3.72	0.118	0.167	12.5	14.9
LSD (*p*=0.05)	16.30	12.15	0.384	0.546	40.9	48.6

Table 5: Effect of nutrient management on root parametersof chickpea and potato

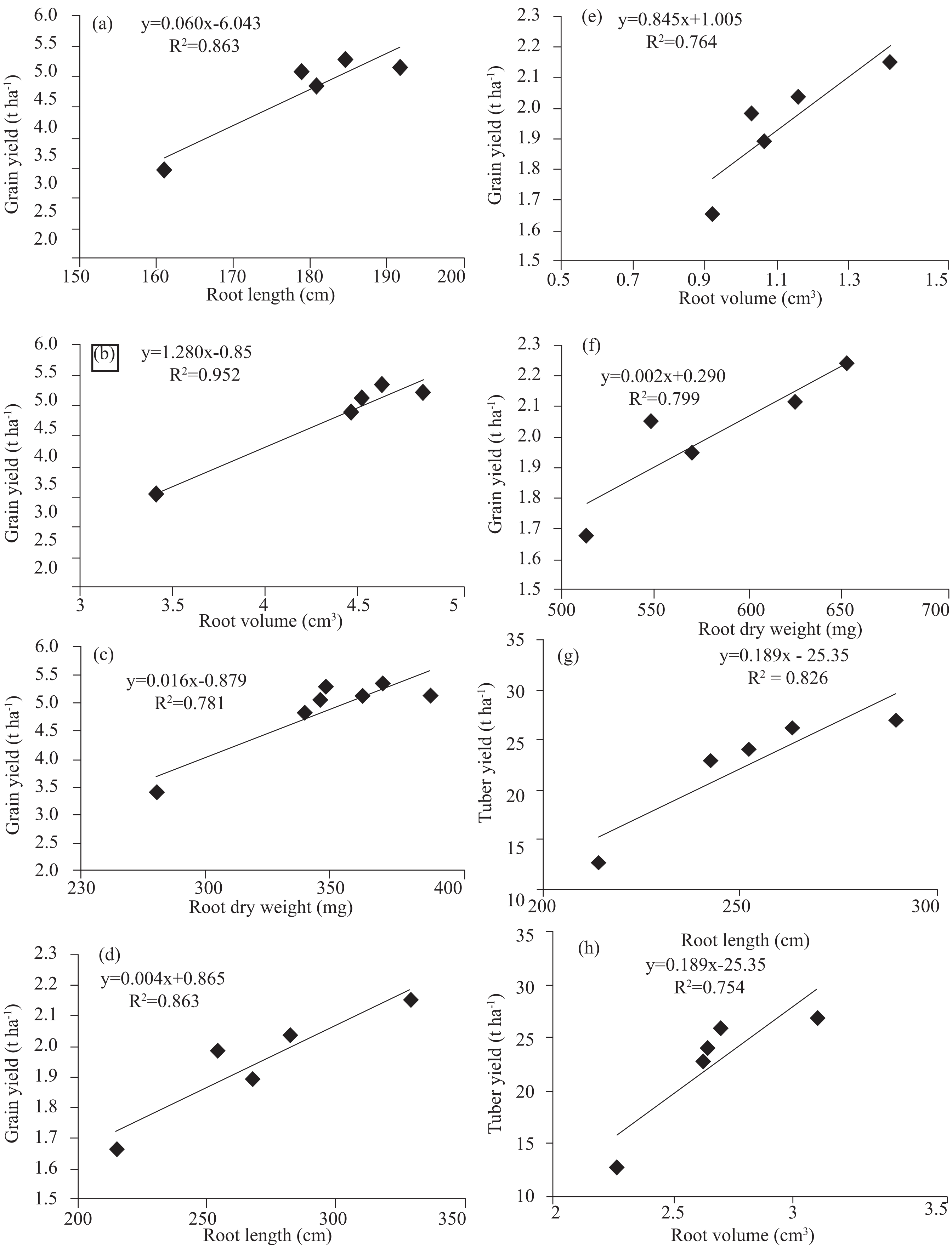
Treatment	Chickpea						Potato					
	Root length (cm)		Root volume (cm^3)		Root dry weight (mg)		Root length (cm)		Root volume (cm^3)		Root dry weight (mg)	
	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13	2011 12	2012 13
Control	211.4	218.2	0.89	0.95	510	518	209.9	218.3	2.21	2.28	0.98	1.06
100% RDF	248.2	259.8	0.98	1.08	540	556	283.2	295.7	3.00	3.12	1.62	1.86
50% RDF+50% RDN-FYM	322.9	335.2	1.38	1.45	648	658	260.8	265.0	2.60	2.72	1.28	1.56
50% RDF+25% RDN-FYM+ biofertilizers	257.5	278.4	1.02	1.11	560	580	239.4	245.3	2.58	2.61	1.18	1.38
25% RDF+50% RDN-FYM+ biofertilizers	270.8	295.0	1.13	1.18	608	642	245.0	259.8	2.56	2.66	1.26	1.46
SEm±	15.27	16.58	0.034	0.036	23.3	24.1	9.03	9.85	0.081	0.100	0.036	0.050
LSD (*p*=0.05)	49.80	54.08	0.111	0.118	75.9	78.7	29.43	32.12	0.265	0.327	0.119	0.163

during both the years of study. This treatment remained at par with all other nutrient sources during 2011-12 and with 100% RDF and 25% RDN+50% RDN through FYM+biofertilizers during 2012-13.

The chickpea grain andstover yields remained significantly highest in the treatment where 50% of RDN was substituted through FYM along with 50% RDF during both the years of study (Table 2). The treatments, 100% RDF and 25% RDF +50% RDN through FYM+biofertilizers remained next in order in grain andstover yields of chickpea. Application of 50% RDF+50% RDN through FYM increased the grain yield of chickpea to the tune of 28.28 and 29.12% over control during 2011-12 and 2012-13, respectively. As the nitrogen requirement of chickpea is low and its growth also remains slow during winter season hence, it was more responsive to organic source and biofertilizers, which made the nutrients available slow and forlonger time to the crop (Ramesh et al., 2009) which in turn increased growth and yield.

3.4. Potato yield

The yield attributes of potato (number of tubers $hill^{-1}$, fresh and dry weight of tubers $hill^{-1}$) and tuber and haulms yields were significantly affected with application of nutrient sources as compared to control (Table 3). The highest values of yield attributes of potato were recorded with the application of 100% RDF followed by 50% RDF+50% RDN through FYM during both the years. Potato tuber and haulms yield were found significantly maximum with the application of 100% RDF followed by 50% RDF+50% RDN through FYM during both the years. However, during 2011-12 all the nutrient sources


(a)
y=0.060x-6.043
R2=0.863
Grain yield (t ha-1)
Root length (cm)
(b)
y=1.280x-0.85
R2=0.952
Grain yield (t ha-1)
Root volume (cm3)
(c)
y=0.016x-0.879
R2=0.781
Grain yield (t ha-1)
Root dry weight (mg)
(d)
y=0.004x+0.865
R2=0.863
Grain yield (t ha-1)
Root length (cm)
(e)
y=0.845x+1.005
R2=0.764
Grain yield (t ha-1)
Root volume (cm3)
(f)
y=0.002x+0.290
R2=0.799
Grain yield (t ha-1)
Root dry weight (mg)
(g)
y=0.189x - 25.35
R2 = 0.826
Tuber yield (t ha-1)
(h)
Root length (cm)
y=0.189x-25.35
R2=0.754
Tuber yield (t ha-1)
Root volume (cm3)

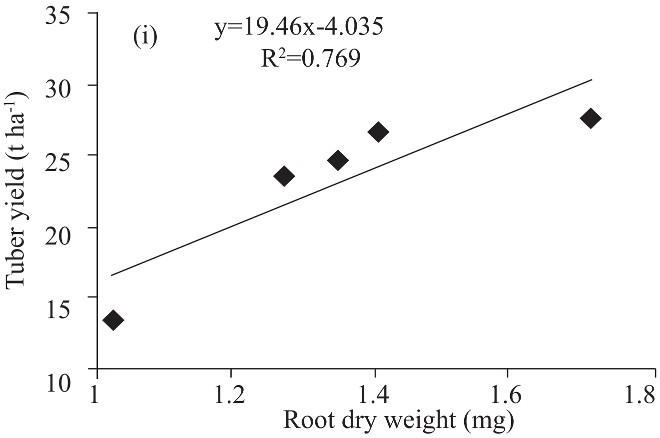


Figure 2: Correlation and regression lines between root parametersandyieldofwheat(a to c),chickpea(d to f)andpotato (g to i)

gave statistically similar tuber yield. The very low productivity of potato was obtained during 2011-12 as the crop was affected by chilling temperature in December-January followed by infestation of late blight. Further, 100% RDF registered an increase of 73.77 and 135.11% tuber yield over control during 2011-12 and 2012-13, respectively. This increasein the yield was mainly owing to the improvement ingrowth as well as yield-attributing characters, with the application of 100% RDF. However the difference in tuber yield with 100% RDF and 50% RDF+50% RDN through FYM was non-significant during next year, attributed to build up of soil fertility due to continuous application of FYM to previous crops. Similar findings were also reported by Kumar et al. (2009); Ayyub et al. (2011).

3.5. Wheat grain equivalent (WGEY) yield

Wheat grain equivalent yield of chickpea and potato showed that chickpea grown in soybean-chickpea-fodder sorghum (CS_3) sequence recorded significantly highest WGEY during both the years of study (Figure 1). The higher WGEY was observed in 2012-13 as compared to 2011-12. This was due to increase in prices of crops and higher yield obtained compared to previous year of study. The potato (CS_4) also recorded statistically at par WGEY with chickpea during 2012-13. This was because of good yield of potato during the year 2012-13.

Among the nutrient management practices, application of 100% RDF (NM1) recorded significantly maximum WGEY during both the years (Figure 1). Substitution of 50% RDN through FYM (NM2) also gave similar WGEY of crops as that of recorded with 100% RDF.

4. Conclusion

Root growth in terms of root length, root volume and root dry weight of wheat and chickpea were observed significantly maximum where 50% RDN was substituted with FYM along with 50% RDF. All the yield parameters and yields of wheat in soybean-wheat-fallow and soybean-wheat-mungbean cropping system did not differ significantly. 100% RDF resulted significantly highest yield and its attributes for wheat and potato; however, 50% RDF+50% RDN through FYM for chickpea

5. References

Aggarwal, P., Choudhary, K.K., Singh, A.K., Chakraborty, D., 2006. Variation in soil strength and rooting characteristics of wheat in relation to soil management.Geoderma 136, 353−363.

Ayyub, C.M., Pervez, M.A., Ali, S., Manan, A., Akhtar, N., Ashraf, I.,Shahld, M.A., 2011. Growth and yield response of potato crop to different sources of potash. International Journal for Agro Veterinary and Medical Science 5(3), 283−288.

Behera, U.K., Sharma, A.R., Pandey, H.N., 2007. Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. Plant and Soil 297(1&2), 185−199.

Chitale, S., Tiwari, A., Bhoi, S., Savu, R.M., Tomar, H.S., Urkurkar, J.S., 2013. Performance of soybean (*Glycine max*)-based cropping sequences under organic, inorganic and integrated nutrient supply systems in a Vertisols. Indian Journal of Agronomy 58(2), 163−167.

Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures for Agricultural Research. John Willley and Sons, NewYork.

Kumar, M., Jatav, M.K., Trehan, S.P., Lal, S.S., 2009. Integrated nutrient management in potato-based cropping systems for eastern Indo-Gangatic plains of India. Potato Journal 6(3&4), 136−142.

Meena, B.L., Singh, A.K., Phogat, B.S., Sharma, H.B., 2013. Effects of nutrient management and planting systems on root phenology and grain yield of wheat (*Triticum aestivum*). Indian Journal of Agricultural Sciences 83(6), 627–632.

Pandey, S.K., Singh, J.P., Gopal, J., 2008. Potato varieties and cropping systems in India. Potato Journal 35(3&4), 103−110.

Ramesh, P., Panwar, N.R., Singh, A.B., Ramana, S., 2009. Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max*)-based cropping systems under organic, chemical and integrated nutrient management practices. Indian Journal of Agronomy 54(3), 278−283.

Sharma, B.M., Singh, R.V., 2007. STCR approach for fertilizer recommendations based on targeted yield concept. Technical Bulletin, Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi (India), 68.

Sharma, K.L., Neelaveni, K., Katyal, J.C., SrinivasaRaju, A., Srinivas, K., Kusuma Grace, J., Madhavi, M., 2008. Effect of combined use of organic and inorganic sources of nutrients on sunflower yield, soil fertility and overall soil quality in rainfed Alfisol. Communications in Soil Science and Plant Analysis 39(11&12), 1791−1831.

Sharma, R.C., Sharma, H.C., Trehan, S.P., Singh, J.P., 2006. Results of permanent manurial trials at Jalandhar. Technical Bulletin 75, Central Potato Research Institute, Shimla, 43.

Tripathi, S.C., Singh, R.P., 2008.Effect of crop diversification on productivity and profitability of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy 53(1), 27−31.

Uwah, D.F., Eneji, A.E., Eshiet, U.J., 2011. Organic and mineral fertilizers effects on the performance of sweet maize (*Zea mays* L.) in south eastern rainforest zone of Nigeria. International Journal of Agriculture Sciences 3(1), 54−61.

Vyas, A.K., Billore, S.D., Chauhan, G.S., Pandya, N., 2008. Agro-economic analysis of soybean-based cropping systems. Indian Journal of Fertilizer 4(5), 41−42, 45−51.

Yadav, R.L., Yadav, D.V., Duttamajumdar, S.K., 2008. Rhizospheric environment and crop production: A review. Indian Journal of Agronomy 53(1), 1−17.

