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Alternative Arable Cropping Strategies: A Key to Enhanced Productivity, Resource-Use-Efficiency, and Soil-Health under Subtropical Climatic Condition

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A B S T R A C T

There are 115 million operational holdings in the country and about 80 % are marginal and small farmers. To fulfill the basic needs of house hold including food (cereal, pulses, oilseeds, feed, fodder, fiber etc.) warrant an attention about Alternative Arable Cropping Strategies (AACS). Undoubtedly, majority of the farmers are doing farming since long back but their main focus was individual components but not in a strategies way. The strategies is made in such a way that product of one component should be the input for other enterprises with high degree of complimentary effects on each other. The information on AACS in a systematic way is presented here. An investigation was undertaken during 2010–20111 to 2014-15 to assess the agro-economic potentiality of ten promising high-value crops alternative arable cropping systems in order to diversify the cereal–cereal based rotations and owning maximum profitability in subtropical climatic condition of western Uttar Pradesh production systems. Maize-potato–onion (M-P-O) system proved as best viable option in realizing highest production efficiency in terms of resource use efficiency, energy dynamic, monetary and employment efficiencies water-use efficiency and enzymatic activities besides enhancing soil health; followed by maize-potato-mungbean (M-P-M_b) system. Cowpea- potato-mungbean (C_p–P–M_b) and Maize-garlic-mungbean (M-G-M_b) system also observed higher net-returns, land use efficiency and monetary-efficiencies. The methodology is explained keeping in mind the work done so far to realize better productivity, profitability and sustainable production systems that would help to solve the fuel, feed and energy crisis, create more employment avenues, ensure regular income and encourage agricultural oriented industry.

Keywords

Profitability, Soil health, Energy relationships, Resource use efficiency.

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Introduction

Rice - wheat is the most dominant crop sequence in the sandy loam soil region of western Uttar Pradesh, India. Continuous cultivation of rice-wheat for longer periods with low system productivity, and often with poor crop management practices, results in loss of soil fertility due to emergence of multiple nutrient deficiency (Dwivedi *et al.*, 2001) and deterioration of soil physical properties (Tripathi, 1992), and decline in factor productivity and crop yields in high productivity areas (Yadav, 1998). During cultivation of rice soil undergoes drastic changes, i.e. aerobic to anaerobic environment, leading to several physical and electro-chemical transformations. Puddling breaks capillary pores, reduces void ratio, destroys soil aggregates, disperses fine clay particles, and lowers soil strength in the puddled layer (Sharma and De Datta, 1986). In systems that are frequently wet and dry, there is potential for significant loss of N by leaching and denitrification. Further, since nitrite is an intermediate in both the reduction of nitrate and the oxidation of ammonia, aerobic denitrification via nitrate may be more substantial and widespread than previously realized, especially on soils that are alternately wet and dry (Ponnamperuma, 1972).

Cassman *et al.,* (1995) proposed that the now commonly observed, smaller than previous response to N fertilizer in continuously flooded rice systems, is associated with sequestration of N in resistant lignin compounds formed from the large amounts of retained crop residues. If this is the case, then perhaps there is an important role for rice rotations that include upland crops, such as wheat and grain legumes, to break this sequestration of N. Diversification and intensification of rice-based system to increase productivity per unit resource is very pertinent. Crop diversification shows lot of promises in alleviating these problems besides, fulfilling basic needs for cereals, pulses, oilseeds and vegetables and, regulating farm income, withstanding weather aberrations, controlling price fluctuctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity (Gill and Ahlawat, 2006). Alternative cropping has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation, and judicious use of land and water resources, sustainable agricultural development and environmental improvement (Hedge *et al.,* 2003). The Alternative cropping crop may enhance profitability, reduce pests, spread out labour more uniformly, reduce risks from aberrant weather by different planting and harvesting times and source of high value products from new crops (Reddy and Suresh, 2009). In the era of shrinking resource base of land, water and energy, resource use efficiency an important aspect for considering the suitability of a cropping system (Yadav, 2002). Hence, selection of component crops needs to be suitably planned to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005).

There is ample scope to diversify Kharif rice with maize, as it has significantly lower irrigation requirement than rice and can enhance the system productivity and sustain soil health and environment quality Singh, 2012. On the other hand, vegetable cowpea is emerging as an alternate option in Kharif season being a high-value legume to enhance farm profitability and soil health as well (Kalia and Kumar, 2012). Onion prices in south-Asia particularly India are relatively high in the months of October–November due to less supply and production in the region and to curtail this price rise, Kharif onion production has great potential in western Uttar Pradesh as mid-term strategy (Gupta, 2013). The area under rainy-season onion crop in India is about 20 % of the total cultivated area; thus, Kharif onion production in non-traditional areas would definitely ensure the availability, price-stabilization and better remunerations to practicing farmers (Choudhary *et al.,* 2013 and Gupta, 2013). Green-chilli is another viable option in Kharif season to meet the peri-urban demand and reap high economic returns (Dey *et al.,* 2012). Potato is a short duration high value cash crop with flexible sowing-window which could be another suitable crop-intensification alternative, besides enhancing farm productivity and profitability (Sharma and Sharma, 2005). Short-duration summer-legume crop mungbean (*Phaseolus radiatus* L.) in western Uttar Pradesh has great potential in enhancing crop-intensification and thus, harnessing better system productivity and profitability (Sharma and Sharma, 2004). Inclusion of mungbean and its' residue incorporation after harvesting of pods is added advantage of N-fixing for resilience soil fertility (Pooniya *et al.,* 2012, and (Sharma and Sharma, 2004).

Overall, alternative cropping strategy in cereal-based production systems is the need of the hour in western Uttar Pradesh both through location-specific cereal replacement and crop-intensification as well (Singh *et al.*, 2011and Singh, 2012). Therefore, the present investigation was conductively undertaken to diversify the cereal-based production systems with productive, resource-use-efficient and remunerative with appropriate and promising vegetable and legume-based systems viz. rice-wheat (R-W), rice-potato- mungbean (R-P-M_b), rice-cabbage-onion (R-C-O), maize-wheat- mungbean (M-W-M_b),maize-potato-mungbean (M-P-M_b), maize-potato-onion (M-P-O),maize-garlic-mungbean (M-G-M_b), cowpea-potato-mungbean (C-P-M_b), Kharif onion-wheat-mungbean (O-W-M_b), and chilli–wheat–mungbean (C_h–W–M_b) to enhance system productivity, profitability and resources use- efficiency; besides ameliorating the production vulnerabilities that RWCS has brought so far.

Materials and Methods

An experiment on alternative arable cropping strategies was conducted during Kharif (wet season), Rabi (dry season) and summer season of the year 2010-111 to 2014–15 in farmers participatory mode in the jurisdiction of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut U.P. India., (28°402073N to 29° 282 113N, 77°282143E to 77° 44 183E) and was designed as a farmer-managed with a single replicate, repeated over many farmers. Therefore, the experimental design was Randomized Block Design in which farmer as a replicate/ block. The climate of the region is broadly classified as semi-arid sub-tropical, characterized by very hot summers and cold winters. The hottest months are May and June when the maximum temperature reaches 45–46°C, while in December and January, the coldest months of the year, the minimum temperature often goes below 4°C. Average annual rainfall is 805 mm, 80% of which is received through the north-western monsoon during June–September. Important characteristics of the 0-15 cm soil layer of the experimental field are presented in Table 1.

Experimental details

The experiment was laid-out in designed as a farmer-managed with a single replicate, repeated over many farmers. Therefore, the experimental design was Randomized Block Design in which farmer as a replicate/ block. Treatments comprised of ten alternative arable cropping strategies viz. rice-wheat (R-W), rice-potato- mungbean (R-P-M_b), rice-cabbage-onion (R-C-O), maize-wheat-mungbean (M-W-M_b), maize-potato-mungbean (M-P-M_b), maize-potato-onion (M-P-O), maize-garlic-mungbean (M-G-M_b), cowpea-potato-mungbean (C_p-P-M_b), onion-wheat-mungbean (O-W-M_b), and chilli–wheat–mungbean (C_h–W–M_b) cropping systems were taken with recommended dose of fertilizers. The details of crops and field cultural operations followed in cropping systems etc. are given in Table 2. A common dose of nutrients amounting 150 kg N + 60 kg P_2O_5 + 40 kg K_2O + 25 kg $ZnSO_4$ ha^{-1} were applied in all treatments during first year of study (2010-11). The 1/3rd N and whole P_2O_5, K_2O and $ZnSO_4$ was applied as basal, while remaining 2/3rd N was top dressed as urea in two equal splits at two vegetative growth phases.

At the time of top dressing, fertilizer was broadcasted and care was taken so that the fertilizers were mainly applied on targeted crop rows only. Proper agronomic practices were followed during crop growth periods. At maturity, the crop was harvested manually and estimates the grain yield. Grain moisture was determined using a grain moisture meter. The grain yield of crops was adjusted at 14% moisture content.

Soil chemical and physical analysis

After drying, the soil samples were drawn for chemical analysis. The available N, P and K were determined using standard procedures mentioned in Table 1. Bulk density of surface (0–15 cm) and sub-surface (15–30 cm) soil was determined by the core sampler method from three randomly chosen spots from each plot (Chopra and Kanwar, 1991). The soil porosity was computed from the relationship between bulk density and particle density using (1):

$$Porosity\,(\%) = 1 - \frac{BD}{PD}\,x100 \quad (1)$$

Where

BD is bulk density (g cm^{-3}), and
PD is particle density (g cm^{-3})

Soil organic carbon (SOC)

Soil organic carbon was determined by wet digestion with potassium dichromate along with 3:2 H_2SO_4: 85% H_3PO_4 digestion mixture in a digestion block set at 120°C for 2 h (Snyder and Trofymow, 1984).

Total organic carbon (TOC)

The TOC content was determined by using Walkley and Black's (1934) rapid titration method and computed using Eq. (2):

TOC stock (Mg C ha^{-1}) = TOC content (g C kg^{-1}) × Db (Mg m^{-3}) × Soil layer (m) × 10 (2)

Where,

Db is bulk density of the particular soil layer (Db values for 0-5 cm and 5-15 cm soil layer were 1.32 and 1.34 Mg m^{-3}), respectively).

Soil sampling for soil quality parameters

Soil samples were taken from the experimental field randomly from each plot after the end of cropping system cycles during five years.

Ten soil cores (5 cm diameter, 0–15 cm depth) were taken from each plot. The soil samples were put in polythene bags and allowed to dry and transported to the laboratory where they were thoroughly mixed and sieved (2 mm mesh).

The soil samples were then stored overnight at 5°C in the dark, and prior to biological analyses they were equilibrated to 22–25°C Pooniya *et al.*, (2012). The micronutrients (Zn, Fe, and Cu) were estimated using the method suggested by Lindsay and Norvell (1978) with inductively coupled plasma spectrophotometer (model ICP-OES XP, Australia.

Measurement of enzyme activities

To determine biological function changes in soil, some enzyme activities were determined by the procedures as described by the different scientists (Guan and Shen, 1984; Guan, 1986; 1989). (1) Na_2RPO_4 (R indicates benzene material) as the medium and measuring releasing content using the color comparison method (P_2O_5 mg/100 g, 37°C, 2 h) for Alkaline phosphatase. (2) Measuring NH_3-N content (NH_3-N mg·g^{-1}, 37°C, 24 h) by the color comparison method, with urea as medium for urease. (3) Measuring glucose content (glucose mg·g^{-1}, 37°C, 24 h) by the color comparison, glucose as the medium for sucrose by using Photo-spectrometer (Guan, 1986). (4) Acid phosphatase (EC 3.1.3.2) enzyme was measured using *p*-nitrophenyl phosphate disodium (0.115 M) as substrate according to Mandal *et al.,* (2007). (5) Dehydrogenase activity was determined by the reduction of triphenyl tetrazolium chloride (TTC) to triphenyl formazan (TPF) as described by Serra-Wittling *et al.,* (1995). (6) Soil invertase activity was measured by incubating 5.0g soil with 15 ml of 8% sucrose solution for 24 h at 37°C. The suspension reacted with 3, 5-dinitrosalicylic acid and absorbance was detected at 508 nm. (7) Protease activity was assayed using the Ladd and Butler method (1972). All determinations of each sample were performed in triplicate, and all values reported are averages of the three determinations expressed on an oven-dried soil basis.

Economic analysis, production indices and monetary efficiencies

In order to determine the cost of cultivation, cost of each input and output were calculated accordingly as per prevailing prices during each year. Gross and net returns per ha were calculated based on the crop productivity and prevailing market prices of different crops during respective crop years/seasons. The system productivity and profitability was calculated by dividing the crop equivalent yield and net returns by 365. The irrigation system productivity was calculated by dividing the crop equivalent yield by the total amount of irrigation water was used to grow the crop (Katyal and Gangwar 2011). Similarly, nutrient use productivity was calculated by dividing the crop equivalent yield by the total quantity of nutrients used in the cropping system. Total system energy input and output was measured based on energy input/output of each crop in respective system. Physical energy of each input and output was converted into energy equivalents viz. Mega Joules (MJ) and Giga Joules (GJ) by using conversion coefficient values given by Gopalan *et al.,* 1978. Energy input–output relationship with respect to energy efficiency, energy productivity and net energy in different cropping systems vary with the component crops knitted in a cropping sequence,soil type, agronomic operations and fertilizers used, plant protection measures and economic produce levels Mandal *et al.,* 2005.

Statistical analysis

All the field and laboratory data on various plant parameters on component crops of different cropping systems was statistically analyzed using the F test as per the procedure given by Gomez and Gomez (1984). Least significance difference (LSD) values at P = 0.05 were used to determine the significant differences between treatment me

Results and Discussion

Production efficiency and land use efficiency

Present experiment revealed that among ten alternative arable cropping systems (AACS) viz. M-P-O, M-G-M_b, R-P-M_b, O-W-M_b and C_h-W-M_b recorded highest production efficiency followed by M-P-M_b, C_p-P-M_b and R-C-O, respectively (Table 3). High production potential of garlic, potato, onion and higher pod yield in cowpea and mungbean, were the possible reasons for getting highest efficiency in this system.

Potato/Onion/Garlic based systems are also more productive and profitable than cereal-based systems due to higher productivity resulting in better remuneration. This discussion holds true in the current study, when highest production efficiency in M-G-M_b was reflected due to residual fertility of legumes tailored in this system (Singh *et al.*, 2011) besides higher supply of macro and micronutrients and soil physical health (Table 5 and 6), due to better phosphatase and dehydrogenase activity by incorporating the SMB biomass (Banik and Sharma, 2009). The land use efficiency under M-P-O, M-G-M_b, R-P-M_b, M-P-O, and M-P-M_b was recorded as 85.1, 84.8, 84.6, 83.4 and 83.3%, respectively which were at par with C_p-P-M_b (82.8%), O-W-M_b system (81.5%) and C_h-W-M_b (80.2%). However, energy value in terms of energy use ratio was only 3.09 over existing R-W system (8.38), respectively.

Energy dynamics and energy use efficiencies

Keeping in view current energy crisis, studies on energy dynamics and energy use efficiency in agricultural production systems also assume great importance to identify promising production systems which have less dependency on non-renewable energy sources. In the current study, the estimation of energy use in different cropping systems revealed that M–P– O utilized highest energy (28.9 GJ ha^{-1}) followed by C_p–P–M_b (26.4 GJ ha^{-1}), M–P–Mb, R-P-M_b and O–W–M_b, respectively. M–P– O system used highest energy input because potato consumes higher energy with respect to fertilizer, seed as well as human labour for earthing-up and digging operations in potato; besides more energy input in pod picking operation both in cowpea and mungbean legumes. C_h–W–Mb and R-C-O sequence also consumed more energy owing to regular spraying of pesticides in chilli crop being prone to wet season diseases besides relatively higher fertilizer and irrigation requirements in chilli and cabbage (Singh *et al.*, 2011. M-G–M_b, C_p–P–M_b and M-P-O systems again exhibited higher energy efficiency because in spite of better energy output by these systems, their energy use per unit energy output was quite lower as compared to other two systems. C_h-W-M_b, O–W–M_b system also produced higher energy equivalents which resulted in greater net energy returns quite close to C_p–P–M_b system was primarily due to higher yield of this system.

Production, monetary and employment efficiencies

Production and monetary efficiencies are the performance indicators of various cropping systems in terms of productivity and monetary gains day^{-1} ha^{-1}, respectively. In current study, highest production efficiency (89.7kg$ha^{-1}day^{-1}$) and monetary efficiency (Rs. 351.6 $ha^{-1}day^{-1}$) were observed in M-P-O which proved significantly superior over rest of the cropping systems (Table 4). M-P-M_b system ranked second and showed superiority over M–W–M_b and C_p–P–M_b. Overall, M-G-M_b cropping system utilized land more efficiently which led to higher production and monetary advantages in the present experimentation. Production efficiency referred as per day productivity of a system under particular treatment depends on production potential of crops taken in that system. Thus, highest production efficiency was observed in C_p–P–Mb sequence because of highest production and gross returns obviously with considerable contributions of cowpea and potato crops. High value crops viz. onion, chilli, garlic, carrot, mungbean and cowpea producing quick returns, are perfect option for small holders to utilize surplus labour and augment their income. The remunerative price from onion resulted in higher net returns in O–W–Mb sequence but higher cost of cultivation is the major drawback for lower benefit: ratio than M-W-M_b rotation.

The data given in Table 3 and 4 revealed that there is sufficient scope to replace rice-wheat cropping system with other cropping systems without any decline in economic yield rather it improved substantially. The M-P-O; C_p-P-M_b, M-P-M_b, M-W-M_b, M-G-M_b and R-C-O gave 2.1, 1.8, 1.7,1.5, 1.3 and 1.1 times more productivity over R-W system which clearly elucidated the superiority of these systems over R-W system. These systems also helped to save 83- 116 cm of irrigation water (Table 3). The M-P-O system gave the highest productivity (89.7kgha^{-1}day^{-1}) and used 83 cm less water than R-W system with a productivity margin of 39.97kgha^{-1}day^{-1}. The summer C_p-P-M_b system gave 83.3kgha^{-1}day^{-1} productivity with 115 cm irrigation water (Table 3 and 4) leading to 103 cm saving of water. M-P-M_b cropping system gave 88.6kgha^{-1}day^{-1}productivity with total irrigation water used as 110 cm, thereby indicating the net saving of irrigation water to the extent of 108 cm.

The M-W-M_b produced 81.2kgha^{-1}day^{-1} productivity and used only 102 cm irrigation water which was 53.2 per cent less than irrigation water used for R-W system (Table 3 & 4). It might be due to the reason that cowpea and mungbean pulse crops have improved the soil physicochemical properties which might have reduced the water loss due to evaporation, percolation and seepage as compared to R-W system (Singh and Malhotra, 2013; Chaudhary *et al.*, 2006). The net returns were maximum Rs. 1, 54, 030 ha^{-1} annum^{-1} in M-P-O system and it was 2.61 times more over R-W system (Table 4). The net returns in the other cropping systems like M-W-M_b, M-G-M_b, M-P-M_b and C_p-P-M_b were Rs. 86,410, 123,933, 126,689 and 138,050, respectively. The quantity of water used in the Ch-W-M_b, M-G-M_b, R-C-O, C_p-P-M_b and M-P-M_b was 32.1, 39.4, 44.9, 47.2 and 49.5 per cent less than quantity of water used for R-W system. The corresponding value in terms of saving of electricity consumption (per ha basis) was 628, 773, 883, 928 and 968 electricity units with electricity bill amounting Rs 3140, 3865, 4415, 4640 and 4840 per ha over R-W system, respectively (Table 4). The C_p-P-M_b system showed the highest water productivity of 2.325 kg grainm-3 irrigation water followed by M-G-M_b and M-P-O (2.216; 2.149 kg grain m^{-3} irrigation water). The least water productivity of 0.635 kg grain m^{-3} irrigation water was observed in R-W cropping system. Similar kinds of reports have also been reported by Bohra *et al.*, (2007); Gill and Sharma (2005).

Resource use efficiency

In the present context of degradation of natural resources and the productivity of crops, the resources efficiency and sustainability of cropping systems are attracting the attention of scientists all over the world. The resources efficiency is a paramount character for the establishment of new cropping system. The cropping system which utilize the farmer's available resources effectively and provide him employment throughout that will be acceptable to the farmers readily. Resource use efficiency of different cropping systems was evaluated through different approaches proposed by Singh *et al.*, (1990); Sharma (2002). Two components i.e. monetary return use efficiency (MRUE) Rs ha^{-1} day^{-1} and system profitability (Rs ha^{-1} day^{-1}) were measured to analyze the efficiency of different cropping systems. The monetary return use efficiency (MRUE) values ranged between 163.9 and 351.6 among alternative arable cropping systems; being lowest in R-W and highest in M-P-O (Table 4). The monetary return use efficiency (MRUE) was above 48 in M-P-O, M-G-M_b and C_p-P-M_b cropping systems. The system profitability among different cropping systems ranged between Rs. 176.8 and 388.9 $ha^{-1}day^{-1}$. The system profitability efficiency like production efficiency was highest in M-P-O and it was distinctly higher than all other cropping systems. The system profitability efficiency was around Rs.320 ha^{-1} day^{-1} in M-W-M_b, M-G-M_b, M-P-M_b and C_p-P-M_b cropping systems (Table 4).

Different cropping systems paid opportunities to the farmers to work for different number of days in a year, in agriculture there is a major problem of under employment and therefore, employment generation efficiency (EGE) cope with the cropping system which employs farmers for more number of days is a boon to the farmers. M-P-O engages farmers almost throughout the year i.e. 1.73 man day ha^{-1} day^{-1}, while C_h-W-M_b and C_p-P-M_b employs farmers for only 1.68 and 1.65 man day ha^{-1} day^{-1}. Almost all cropping systems do not engage farmers for more than 0.64 man day ha^{-1} day^{-1} and it reflects under-employment in agriculture (Table 4). These data indicate that the farmers must go for agri-business along with raising cropping. These results corroborate the findings of Gangwar and Baldev (2005), Chandrappa *et al.,* (2005), Bastia *et al.,* (2008), Sharma *et al.,* (2007).

Soil fertility status

C–P–Mb sequence exhibited higher value of soil available— N, P and K analyzed after 5 years of the sequence (Table 5); which might be due to incorporation of mungbean residues and inclusion of another legume cowpea having relatively higher above ground leaf biomass and below ground root biomass additions. Thus, higher root and shoot biomass additions might also be possible reasons for higher OC in C_p–P–M_b cropping system (Dwivedi *et al.,* 2003; Sharma and Sharma, 2004). The available N-status monitored after 5 years of cropping systems indicated the improvement in N status over its initial value (165.8kg ha^{-1}). The lowest N-status was recorded in R-W cropping system (162.8kgha^{-1}). The M-P-M_b and M-P-O being input intensive high yielding systems showed comparatively better levels of available nitrogen but these were also found in the low category (Table 5). These results are in agreement with the findings of Idnani and Singh (2008).

C_p–P–M_b exhibited lower available K in soil over other sequences because potato is a heavy feeder of K and a good crop of potato removes about 250 kg K ha^{-1}. On the contrary, M–W–M_b system exhibited highest available K in soil because potato and Kharif onion imbedded cropping systems remove higher amounts of K (Choudhary and Suri, 2014). Inclusion of legumes and in-situ incorporation of mungbean residues led to an increased OC and available N. Beneficial effect of legume residues to better nutrient reserves and favorable buffering capacity besides enhancing bio-availability of N and native P. It also releases organic colloids having higher cation exchange sites attracting K from applied K and non-labile pool onto exchangeable pool which ultimately favours available K status in soil (Lund and Doss, 1980). The maximum buildup of K was accrued in maize based cropping systems (203.2 to 207.9 kgha^{-1}). The lowest value was recorded in rice-wheat system (185.8 kgha^{-1}) which was 11.9, 11.8 11.2 and 9.4 per cent lower than M-P-O, M-G-M_b, M-P-M_b and M-W-M_b systems, respectively. These results are in agreement with the findings of Kumar *et al.,* (2008). The differences in organic carbon (O.C.) content were observed in various cropping systems; being markedly higher in C_p-P-M_b, M-G-M_b, M-P-O and M-P-M_b cropping system. The organic carbon content in all the cropping systems increased over initial except R-W cropping system.

Table.1 Physico-chemical properties of experimental soil at initiation of field experiment

Soil parameters	Status/value	Methods employed
Mechanical separates		
i. Sand	63.0	Modified hydrometer Bouyoucos, (1962)
i. Silt	16.2	
i. Clay	20.4	
Textural class	Sandy loam	
Bulk density (Mg m^{-3})	1.40 (0-15 cm)	Core sampler
	1.46 (15-30 cm)	
Water stable aggregates (>0.25mm)	48.5	Wet sieving Haynes, (1993)
Moisture at field capacity (%)	15.5	
Soil chemical properties		
I. Soil reaction (P^H)	7.5	1:2.5 soil & water suspension Jackson, (1967)
I. Organic carbon (%)	0.36	Rapid titration method Walkley and Black (1934)
I. Available nutrients (kg ha^{-1})		
N	165.8	Alkaline permanganate method Subbiah and Asija (1956)
P	12.5	0.5 M $NaHCO_3$, P^H 8.5 Olson *et al.*, (1954)
K	193.2	Ammonium acetate Hanway and Heidel (1952)

Table.2 Details of agronomic practices followed for different crops in field experimentation during 2010–2011 to 2014–2015

Crop in rotation	Seed rate kg ha^{-1}	Date of sowing/ transplanting	Date of harvesting
Rice (*Oryza sativa* l)	25	3rd week of June	3rd week of October
Wheat (*Triticum aestivum* L.)	100	2nd week of November	2nd week of April
Maize (*Zea mays* L.)	20	1st week of July	2nd week of October
Mungbean (*Phaseolus radiatus* L.)	25	3rd week of April	3rd week of June
Cowpea (*Vigna unguiculata* L. Walp.)	30	1st week of July	3rd & 4th week of Sept.
Pearlmillet (*Pennisetum glaucum*)	5-6	2nd week of June	lVth week of September
Potato (*Solanum tuberosum* L.)	2000	3rd week of October	1st week of March
Cabbage (*Brassica oleracea*)	750-1000 gm	3rd week of Sept. -1st week of Oct.	3rd & 4th week of October
Kharif Onion (*Allium cepa* L.)	4-5	1st week of July	1st week of November
Garlic	300-400	lVth week of Sept. - 1st week of Oct.	1st week of March

Table.3 System efficiency and energy use pattern under alternative cropping systems

Crop Sequences	Duration of crops (days)	Land use efficiency (%)	Production efficiency ($kg^{-1}ha^{-1}$ day^{-1})	Total input energy ($GJha^{-1}$)	Specific energy ($MJha^{-1}$)	Energy use ratio	Net energy ($GJ ha^{-1}$)	Irrigation water applied ($cm ha^{-1}year^{-1}$)
R-W	256.6	70.4	16.1	21.2	3.91	8.38	42.9	218
R-P-M_b	317.5	84.8	37.64	25.5	4.77	3.09	49.9	178
R-C-O	310.1	83.3	31.36	23.8	3.95	3.63	50.1	120
M-W-M_b	297.8	76.3	29.80	21.9	4.13	3.77	46.8	102
M-P-M_b	309.4	83.4	33.37	28.9	4.96	3.96	48.3	110
M-P-O	311.7	85.1	38.86	25.7	5.71	3.85	50.8	135
C_h-W-M_b	266.7	80.2	34.37	23.8	4.97	3.82	46.4	148
O-W-M_b	315.8	81.5	35.49	23.2	4.20	3.89	51.7	152
M-G-M_b	289.6	84.6	38.18	23.1	5.02	3.84	61.7	132
C_p-P-M_b	302.2	82.8	32.59	26.4	5.49	3.74	55.6	115

Table.4 Efficiency of various crop sequences (mean of 5 cropping cycles)

Crop Sequences	WUE (kg grain/ m^3 water used)	Electric consumption	Cost of electricity consumption	MRUE (Rs/ha/day)	EGE (man day/ha/day)	Productivity (kg/ ha/day)	Net return (Rs./ha)	System Profitability (Rs/ha/day)
R-W	0.635	1963	9815	163.9	0.64	49.8	59,091	176.8
R-P-M_b	0.863	1586	7930	173.0	1.18	67.4	108,262	216.9
R-C-O	1.058	1080	5400	183.0	1.57	78.5	118,027	254.3
M-W-M_b	1.856	917	4585	241.7	1.21	81.2	86,410	374.2
M-P-M_b	1.864	995	4975	260.6	1.41	88.6	126,689	346.2
M-P-O	2.149	1215	6075	351.6	1.73	89.7	154,030	388.9
C_h-W-M_b	1.283	1335	6675	232.4	1.68	79.6	93,721	229.2
O-W-M_b	1.384	1370	6850	270.1	1.25	71.8	102,142	288.8
M-G-M_b	2.216	1190	5950	343.5	1.38	80.3	123,933	359.3
C_p-P-M_b	2.325	1035	5175	315.6	1.65	83.3	138,050	328.6

WUE = Water use efficiency, MRUE = Monetary return use efficiency, EGE = Employment generation efficiency

Table.5 Soil fertility status after 5 cropping cycles (0-15 cm depth)

Crop Sequences	N (kg/ha)	P (kg/ha)	K (kg/ha)	C:N ratio	Zn($\mu g g^{-1}$)	Fe ($\mu g g^{-1}$)	Cu (μg g^{-1})	OC (%)
R-W	162.8	12.9	185.8	11.4	0.4	4.3	0.3	0.42
R-P-M_b	168.7	12.8	197.1	16.7	0.7	5.9	0.5	0.45
R-C-O	177.3	14.4	200.2	14.1	0.5	5.4	0.3	0.47
M-W-M_b	181.0	13.5	203.2	14.4	0.9	4.9	0.4	0.49
M-P-M_b	181.4	13.2	206.7	13.6	0.6	6.6	0.5	0.53
M-P-O	182.8	19.3	207.9	14.3	0.5	4.8	0.4	0.54
C_h-W-M_b	172.9	14.6	198.7	15.6	0.7	5.1	0.4	0.51
O-W-M_b	183.7	14.7	199.6	12.6	0.7	5.5	0.4	0.51
M-G-M_b	185.7	23.6	207.7	13.7	0.6	6.1	0.5	0.53
C_p-P-M_b	176.8	18.2	198.8	11.7	0.8	5.7	0.4	0.55

*Initial OC (%) = 0.43

Table.6 Effect of alternative cropping systems on the soil enzymatic activities

Crop Sequences	Invertase (mgg^{-1})	Protease (µg)	Acid Phosphatase (µg)	Alkaline Phosphatase (µg)	Urease (µg)	Sucrase (glucose mg·g^{-1})	Dehydrogenase (µg)
R-W	1.86	63.1	134.4	2553.4	24.4	59.66	29.2
R-P-M_b	3.53	82.1	169.4	2842.9	26.3	77.46	45.7
R-C-O	3.26	78.1	182.9	2862.1	42.7	57.05	36.9
M-W-M_b	2.80	86.7	171.4	2798.6	28.1	60.70	45.2
M-P-M_b	3.78	90.4	183.1	2823.1	29.9	55.71	53.7
M-P-O	3.81	105.2	210.6	2897.8	39.9	50.87	41.6
C_h-W-M_b	2.36	119.7	221.1	3041.4	43.5	72.32	61.6
O-W-M_b	3.67	112.2	218.3	2882.8	44.6	54.22	62.5
M-G-M_b	3.57	93.5	189.2	2930.6	31.8	47.74	49.2
C_p-P-M_b	3.98	100.4	197.8	2908.4	37.3	44.46	63.8

Table.7 Effect of 5 years of application of treatments on soil physical properties and total organic carbon (TOC) and soil organic carbon (SOC)

Crop Sequences	Cation exchange capacity (cmol kg^{-1})	Total Porosity (%)	Hydraulic Conductivity (mm h^{-1})	TOC (g kg^{-1})		SOC (g kg^{-1})	
				0-5 cm	5-15 cm	0-5 cm	5-15 cm
R-W	16.87	29.53	53.5	10.99	9.01	4.5	3.6
R-P-M_b	17.21	32.65	48.5	19.64	15.68	7.9	6.8
R-C-O	18.72	37.98	46.3	18.50	14.35	5.9	4.5
M-W-M_b	19.86	41.58	45.6	19.30	15.47	7.2	6.6
M-P-M_b	20.17	46.58	43.8	23.00	18.98	6.5	5.8
M-P-O	22.04	54.25	28.9	25.68	21.63	9.6	8.3
C_h-W-M_b	21.93	51.86	38.6	21.40	17.30	8.1	7.2
O-W-M_b	21.33	52.36	35.3	21.47	18.80	8.4	7.3
M-G-M_b	20.89	49.74	41.6	23.65	19.08	8.6	7.6
C_p-P-M_b	22.40	53.01	32.3	23.87	19.98	9.2	8.1

EDTA-extractable micronutrients (Zn, Fe, Cu)

After completion of each cropping-cycle in 5 years' field experimentation, EDTA extractable zinc (Zn), iron (Fe) and copper (Cu) were improved over initial fertility status. These micronutrients have also registered a slight improvement during the year of study over the first year status of the experimental plots irrespective of the cropping systems indicating that cowpea and mungbean residue have positive bearing on micronutrient build-up in the current study (Table 5). M–W–M_b system registered highest magnitude of EDTA extractable Zn followed by C_p–P–M_b, O–W–M_b, and C_h–W–Mb system, respectively during experimentation (Table 5) while M–P–M_b, M-G-M_b and R-P-M_b systems were the superior sequence in terms of realizing highest value of EDTA extractable Fe and Cu in soil. The maize/cowpea/chili/onion based cropping systems maintained the higher levels of zinc, iron and copper as compared to the rice-wheat cropping system (Table 5). However, all the values of micronutrients under different cropping systems were in sufficient range.

Soil enzymatic activities

The activities of all enzymes varied significantly among different alternative cropping systems. The activities of all enzymes were generally higher in the vegetables and pulse treatment than in the rice-wheat treatment (Table 6). The invertase activity was recorded 3.262 mg·g^{-1}. It can be clearly observed from the results that the enzymatic activity increased in all the alternative arable cropping system treatments as compared to rice-wheat cropping system control during study periods. Symbiotic soil microorganism activity increased with the increase in metabolism of symbiotic roots. With the increase of root exudation, microbes can release substances into soil such as humus. Soil degradation, improves the soil enzymatic activity of soil microorganisms in the soil ecosystem. Increase in the number of microbes and enhanced microbial activity improve the soil. With the decrease of temperature, soil microbial activity also decreased that leads to limits the soil enzymatic activity. After the winter season, in April when mungbean was sown, the symbiotic activity increased and C_p-P-M_b cropping system showed higher concentration of invertase (3.98 mg·g^{-1}) followed by M-P-M_b, M-P-O, O-W-M_b, M-G-M_b and R-P-M_b cropping systems, however the lowest value was recorded in the R-W cropping system (1.86 mg·g^{-1}). These results are supported by (Spedding *et al.*, 2004; Hu and Zhang, 2001) stating that microbe activity had a strong effect on soil enzymes. The soil microbial activity is an important factor for soil formulation and nutrient cycling due to their critical involvement in many soil ecosystem processes.

The activity of urease derived from Table 6 clearly depicts that with the passages of time, the activity of urease shows increasing trend in all treatments. Before alternative cropping system the urease activity was recorded 34.85 µg. During experimentation rabi season, increasing trend were observed in the activity with O-W-M_b, C_h-W-Mb, R-C-O, M-P-O and C_p-P-M_b cropping systems and comparatively lower value was seen in the R-W and M-W-M_b cropping system. It was clear from the results that alternative cropping systems of R-W had great influence on the activity of urease. Urease was the most prominent enzyme in the cycling of carbon and insights into the uptake of nutrients in soils as affected by land management, such as cropping systems. Many researchers described that the soil enzymes activity can be used as sensitive indicator of changes in soil biological activity and fertility in response to various soil management practices (Gajda *et al.*, 2000; Martyniuk *et al.*, 2001). Soil enzymes play important role in the phenomenon of soil that affects the soil fertility and soil metabolism. Plant root exudates' generates about 90% of the soil metabolic activity affecting the contents of soil enzymes directly or indirectly. Plant roots secrete extracellular enzymes and stimulants the soil microbial activity. According to Shun and Tong (2001), soil enzymatic activities are relative to trend and strength of biochemical process, which directly affect the soil productivity, ecosystem performance and economy. Urease showed close relationship with urea hydrolyzation and increase the utilization rate of nitrogen fertilizer (Klose and Tabatabai, 1999). Application of nitrogen fertilizers significantly decreased urease activity, while adding green manure increased its activity. It seems greater enzyme activities in green manure treated soil and are the key factors for more effective soil nutrient cycling mechanisms that are so critical to soil productivity, and in turn, essential to the sustainability of low-input alternative arable farming systems.

The soil alkaline phosphatase activity was 2853.21 µg before alternative arable cropping systems during the year of study. Table 6 revealed that the activity of enzyme increased after one month of alternative arable cropping systems during October in all treatments as compared to the R-W and M-W-M_b cropping systems. In March 2015, alkaline Phosphatase activity was recorded at the highest level (3241.4 μg) in C_h-P-M_b cropping system treatment. The activity directly influenced the decomposition of soil organic phosphorus transformation and bioavailability. The results revealed that at the time C_h-W-M_b, M-G-M_b, C_p-P-M_b, M-P-O and O-W-M_b cropping systems the enzymes activity were showed upward trend followed by M-P-M_b, R-C-O and R-P-M_b but with the passage of time the activity showed downward trend. However, the inter-treatment trend was same i.e. C_h-W-M_b > M-G-M_b> C_p-P-M_b, respectively. Alkaline Phosphatase deal with phosphorus decomposition and improve soil phosphorus validity (Pascual *et al.,* 2002).

There were no differences in acid phosphatase activity between the C_h-W-M_b, O-W-M_b, M-P-O and C_p-P-M_b treatment. The protease and phosphatase activities in the R-W treatment were significantly lower than in the C_h-P-M_b, O-W-M_b, M-O-P and C_p-P-M_b treatments. As shown in Table 6, acid phosphatase generally increased with alternative arable cropping systems. Increased phosphatase activity could be responsible for hydrolysis of organically bound phosphate into free ions, which were taken up by plants. Plants can utilize organic P fractions from the soil by phosphatase activity enriched in the soil–root interface (Yosefi *et al.,* 2011. The increases observed in enzymatic activities due to alternative arable cropping systems are in accordance with previous studies. Martens *et al.,* (1992) reported that vegetable and pulse crops for addition of the organic matter maintained high levels of phosphatase activity in soil during a long-term study. There are several reports about soil organic matter increases resulting from legume green manuring, even without any complementary addition of FYM and compost as it is frequently prevalent in organic farm management (Drinkwater *et al.,* 1998). The effect of organic amendments on enzyme activities is probably a combined effect of a higher degree of enzymes stabilization to humic substances and an increase in microbial biomass with increased soil carbon concentration (Martens *et al.,* 1992). This is also indicated by the strong correlation of protease, acid phosphatase and urease with microbial soil C concentrations (Nayak *et al.,* 2007).

Dehydrogenase is a very useful soil enzyme as it occurs only in live cells, and it can provide an index of endogenous soil microbial activity since its assay involves no addition of a substrate that would preferentially stimulate any particular group of soil organisms. Dehydrogenase should be very useful for the assessment of soil microbial responses to green manuring because they are believed to be linked primarily with microbial activities that are associated with the initial breakdown of organic materials (Bolton *et al.,* 1985). The activity of dehydrogenase was the lowest in R-W cropping system and was increased by the AACS in which green manure including rotation (Table 6). Soil microbial metabolism was greatly enhanced due to legume green manure application (Elfstrand *et al.,* 2007). Stronger dehydrogenase activity in C_p-P-M_b, O-P-M_b and C_h-W-M_b plots may be due to higher organic matter content (Wlodarczyk *et al.,* 2002). These results were similar to our findings that dehydrogenase in rhizosphere soil of alternative arable cropping system i.e. C_p-P-M_b treatment was on average two times higher than that of R-W plots (Table 6). Irrespective of AACS, C_P–P–M_b sequence showed sizable increment in enzymatic activities might be due to exudation of organic substances from root biomass especially legumes which act as substrate to soil microbes, and thus, encourage the dehydrogenase activity and microbial population in the soil.

Cation exchange capacity

Cation exchange capacity (CEC) was also increased due to alternative arable cropping systems. The highest CEC increase under alternative arable cropping systems (32.8%) was found in C_p-P-M_b followed by M-P-O (30.6%) and C_h-W-M_b (29.9%). R-W cropping system showed the lowest increase of CEC from the experimentation (Table 7).The large loss of aggregate stability for the R-W system is of particular concern, as it suggests that the increased aggregate stability of surface soil under R-W is due to puddling rather than an intrinsic property of R-W cropping system. This observation is consistent with that of Hammer beck *et al.,* (2012).

Total porosity and hydraulic conductivity

Soil porosity results showed that alternative arable cropping systems plots could increased the total porosity of soil, while R-W cropping system would decrease the soil porosity for aeration; as a result, it enhances the water holding capacity of soil along with bad aeration of soil.

However, the effects of alternative arable cropping systems on the total porosity were significant. Alternative arable cropping systems plots shown an improvement in the soil porosity and was most probably related to the beneficial effects of soil organic matter caused by residue cover (Table 7). Oliveira and Merwin, 2001 found that the increased porosity was especially important for the crop development since it may have a direct effect on the soil aeration and enhances the root growth. The improved root growth would hence increase plant water as well as nutrient uptake. Within the alternative arable cropping systems, M-P-O, C_p-P-M_b, O-W-M_b, C_h-W-M_b, M-G-M_b, and M-P-M_b produced more porosity than R-W cropping system. Husnjak and Kosutic (2002); Naresh *et al.,* (2014) reported that higher BD reduced the total porosity and changed the ratio of water holding capacity to air capacity in favour of water holding capacity.

Soil organic carbon (SOC)

Results of alternative arable cropping systems after five years significantly influenced the total organic carbon (TOC), and soil organic carbon (SOC) content of the surface soil is depicted in (Table 7). Data indicate that R-W cropping system have a resulted in highly significant losses of SOC ranging from 5.94 to 8.47% for both the 0–5 and 5–15 cm depths. In surface soil (0-5 cm layer) highest soil organic carbon change (12.68%) was found in M-P-O cropping system plots followed by C_p-P-M_b cropping system plots (11.89%).The adoption of alternative arable cropping systems of M-P-O and C_p-P-M_b for five crop cycle increased soil organic carbon by 53.12% and 51.09% more than that of R-W cropping systems, respectively.

These treatments were statistically similar and significantly higher from all other treatments. Irrespective of alternative arable cropping systems in 0– 5 cm soil layer enhanced 55.9% and 63.2% TOC and SOC, respectively, in surface soil as compared to R-W cropping system. Similar increasing trends were observed in 5 -15 cm soil layer, however, the magnitude was relatively lower (Table 7). The higher content of SOC in the surface soil is because the organic matter is usually incorporated in the surface layer and left over residues of shallow-rooted crops like mungbean and cowpea also gets accumulated in the top few centimeters of the soil Naresh *et al.,* 2015.

Our study corroborates that M-P–O; cropping systems proved as an alternate viable option in realizing higher crop productivity, enzymatic activities production efficiency, energy relationships and nutrition as the result of improved resource use efficiency without deteriorating soil physicochemical and microbiological properties rather being vital for OC restoration, nutrient turnover and soil health. M-P-M_b cropping system was found second better alternative with respect to above production parameters and soil health indices. Overall, high-value crops imbedded C_p-P-M_b and M-G-M_b systems may prove as best AACS for enhancing productivity, profitability, nutrient recycling and long-term soil fertility in the subtropical climatic condition of western Uttar Pradesh, India.

This research offered an orientation towards alternative arable cropping strategies model with regard to its evaluation and implication dimensions and it can help achieving sustainability of farms depending on the nature of the resources available for farmers and promote food security in the region. Nevertheless, there is a need for more quantitative assessment of the productivity potential of alternatively arable cropping systems of subtropical climatic condition of western Uttar Pradesh, India under different management practices for different soil types, climates and agricultural systems by supporting existing long term cropping system trial sites and the establishment of new ones where appropriate; quantifying interactions of resource use efficiency and developing farm profitability models that can account for locally relevant agricultural management practices.

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References

Anderson R.I. 2005. Are some crops synergistic to following crops? *Agron J* 97(1): 7-10

Banik P. and Sharma R.C. 2009. Effect of organic and inorganic sources of nutrients on the winter crops-rice cropping system in sub-humid tropics of India. *Arch Agron Soil Sci* 55:285–294

Bastia D.K., Garnayak L. M. and Barik T. K. 2008. Diversification of rice (*Oryza sativa*) wheat (*Triticum aestivum*) based cropping systems for higher productivity, resource use efficiency and economics. *Indian J Agron* 53 (1): 22-26.

Bohra J.S., Singh R.K., Singh U.N., Singh Kalyan and Singh R.P. 2007. Effect of crop Diversification in rice-wheat cropping system on productivity, economics, land use and energy use efficiency under irrigated ecosystem of Varanasi. *Oryza*, 44 (4): 320-324.

Bolton J., Elliott L. F., Papendick P.R. and Bezdicek D.F. 1985. Soil microbial biomass and selected soil enzyme activities: effect of fertilization and cropping practices. *Soil Biol Biochem* 17: 297-302.

Bouyoucos G.J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agron J* 54:464–465

Cassman K.G., Olk D.C., Brouder S.M. and Roberts B.A. 1995. The influence of moisture regime, organic matter and root ecophysiology on the availability and acquisition of potassium: implications for tropicallowland rice. In: Potassium in Asia. Proceedings of the 24th International Colloquium of the International Potash Institute. International Potash Institute, Basel, pp. 135-156.

Chandrappa H., Prabhakara B.N., Mallikarjuna G.B. and Denesh G.R. 2005.

Identification of efficient, employment generative and profitable cropping systems for southern transitional zone of Karnataka. *Indian Agri Sci* 75 (8): 490-92

Chopra SL and Kanwar JS.1991. Analytical agriculture chemistry, 4th edn. Kalyani Publishers, New Delhi, p 301

Choudhary A.K. and Suri V.K. 2014. Integrated nutrient management technology for direct seeded upland rice (Oryza sativa) in NW Himalayas. *Commun Soil Sci Plant Anal* 45:777–784

Choudhary A.K., Thakur S.K. and Suri V.K. 2013. Technology transfer model on integrated nutrient management technology for sustainable crop production in high value cash crops and vegetables in north-western Himalayas. *Commun Soil Sci Plant Anal* 44:1684–1699

Dey B., Singh M.K., De C., Singh V.K. and De N. 2012. Economic analysis on chilli production in the Gangetic alluvial soil. *Inter J Agric Environ Biotech* 5:31–34

Dwivedi B.S., Shukla A.K., Singh V.K. and Yadav R.L. 2001. Results of participatory diagnosis of constraints and opportunities (PDCO) based trials from the state of Uttar Pradesh. In: Subba Rao, A., Srivastava, S. (Eds.), Development of Farmers' Resource Based Integrated Plant Nutrient Supply Systems: Experience of a FAO–ICAR–IFFCO Collaborative Project and AICRP on Soil Test Crop Response Correlation. IISS, Bhopal, India, pp. 50–75

Dwivedi B.S., Shukla A.K., Singh V.K. and Yadav R.L. 2003. Improving nitrogen and phosphorus use efficiencies through inclusion of forage cowpea in the rice–wheat systems in the Indo-Gangetic plains of India. *Field Crops Res* 84:399–418

Elfstrand S., Ba B., and Rtensson M. 2007. Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. *Appl Soil Ecol* 36: 70-82.

Gajda A., Martyniuk S., Stachyra A., Wroblewska B. and Zieba S. 2000. Relations between microbiological and biochemical properties of soil under different agro-technical conditions and its productivity. *Polish.J. Soil Sci.*, 33: 55

Gangwar B. and Ram Baldev. 2005. Diversification Opportunities in rice-wheat cropping. In Alternative Farming System Edited by Singh A. K., Gangwar B and Sharma S.K. 2005 FSRDA, PDCSR, Modipuram, Meerut :154-162

Gill M.S. and Ahlawat I.P.S. 2006. Crop diversification and its role towards sustainability and profitability. *Indian J Ferti* 2 (9): 125-138

Gill M.S. and Sharma G.C. 2005. Cropping system diversification opportunities and conservation agriculture. *J.Farming Systems Research & Development.* 11(2): 127-134

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research. Second Edition, An international rice research institute book. Wiley-Inter-Science Publication, Wiley, New York

Gopalan C, Sastri B. V. R. and Balasusbramanium S. C. 1978.*Nutritive value of Indian Food.* pp 66-144.National Institute of Nutrition Indian Council of Medical Research Hyderabad, Andhra Pradesh.

Guan S.Y. 1986. *Soil Enzyme and Study Methods of Soil Enzyme*. Beijing: Agriculture Publication House

Guan S.Y. 1989. Studies on the factors influencing soil enzyme activities. *Acta Pedologica Sin.*, 26: 72–78

Guan S.Y. and Shen G.Q. 1984. Enzyme activities in main soil in China. *Acta Pedologica Sin.*, 21: 368-381

Gupta R.P. 2013. Onion production: Challenges and ways to meet out the demand of the country, India. In: Holmer R, Linwattana G, Nath P, Keatinge JDH (eds) Proceedings of regional symposium on high value vegetables in southeast Asia: production, supply and demand. AVRDC-World Vegetable Centre, Publication No.

12-758, pp 124–134

Hammer beck A.L., Stetson S.J., Osborne S.L., Schumacher T.E. and Pikul Jr., J.L.2012. Corn residue removal impact on soil aggregates in a no-till corn/soybean rotation. *Soil Sci Soc Am J*., 4: 1390–1398.

Hanway J.J. and Heidel H. 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory, Bulletin 57. Iowa State College of Agriculture, USA, p 131

Hegde D.M., Prakash Tiwari S. and Rai M. 2003. Crop diversification in Indian Agriculture Agricultural Situation in India. August, 2003. pp. 351-354.

Hu H.B. and Zhang J.C. 2001. Study on soil enzyme activity of main forest types in rock coastal area. *J. Nanjing For. University,* 25: 21–25

Husnjak S., filipovic D. and Kosutic S. 2002. Influence of different tillage systems on soil physical properties and crop yield. *Rostlinna Vyroba*, 48 (6): 249–254.

Idnani L. K. and Singh Raman Jeet. 2008. Effect of irrigation regimes, planting and irrigation methods and arbuscular mycorrhizae on productivity, nutrient uptake and water use in summer green gram (*Vigna radiata* var *radiata*) *Indian J Agri Sci* 78: 53-57.

Jackson M.L. 1967. Soil chemical analysis. Prentice Hall of India Ltd, New Delhi, pp 219–221

Kalia P.K. and Kumar R. 2012. Agro-techniques for vegetable production. Indian Agricultural Research Institute Publication No. ICN-H-110/2012, pp 1–55

Katyal V. and Gangwar B. 2011.*Statistical Methods for Agricultural Field Experiments.* P 89.New India Publisingh Agency, Pitampura, New Delhi, India.

Klose S. and Tabatabai M.A. 1999. Urease activity of microbial biomass in soils. *Soil Biol. Bioch.*, 31: 205–211

Kumar Alok, Tripathi H.P., Yadav R.A. and Yadav D.S. 2008. Diversification of rice (*Oryza sativa*) - wheat (*Triticum aestivum)* cropping system for sustainable production in eastern Uttar Pradesh. *Indian J. Agron*. 53 (1): 18-21.

Ladd J.N. and Butler J.H.A.1972. Short-term assays of soil proteolytic enzyme activities using proteins and peptide derivates as substrates. *Soil Biol Biochem*. 4:19–30.

Lindsay W.L. and Norvell W. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci Soc Am J*. 42:421–428

Lund Z.F. and Doss B.D. 1980. Residual effects of dairy cattle manure on plant growth and soil properties. *Agron J* 72:123–130

Mandal A., Patra A.K., Singh D., Swarup A. and Masto R.E. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. *Biores Technol* 98: 3585-3592.

Mandal K.G., Saha K.P., Hati K.M., Singh V.V., Misra A.K., Ghosh P.K. and Bandyopadhyay K.K. 2005. Cropping systems of central India: an energy and economic analysis. *J Sustain Agric* 25: 117–140

Martens D.A., Johanson J.B. and Frankenberger J.W.T. 1992. Production and persistence of soil enzymes with repeated addition of organic residues. *Soil Sci* 153: 53-61.

Martinez V.A., Rowland D., Sorensen R.B. and Yeater K.M.2008. Microbial community structure and functionality under peanut-based cropping systems in a sandy soil. *Biol. Fert. Soils*, 44: 681-692.

Martyniuk S., Gajda A.and Kuś J. 2001. Microbiological and biochemical properties of soil under cereals grown in the ecological, conventional and integrated systems. *Acta Agro.Physica*, 52: 185

Naresh R.K., Dhaliwal S.S.,Kumar D., Tomar,S.S.,Misra, A.K.,Singh S.P., Kumar, P., Kumar V. and Gupta R. K. 2014. Tillage and Rice-Wheat Cropping Systems Influences on Soil Physical Properties; water balance and Wheat Yield under Irrigated Conditions. *AJAR;* 9

(32): 2463-2474

Naresh R.K.,Gupta Raj K., Gajendra Pal, Dhaliwal S.S., Kumar Dipender, Kumar Vineet, Arya Vichitra Kumar, Raju, SinghS.P., Basharullah and Singh Onkar. 2015. Tillage Crop Establishment Strategies and Soil Fertility Management: Resource Use Efficiencies and Soil Carbon Sequestration in a Rice-Wheat Cropping System. *Eco Environ Con.* 21: 121-128

Őhlinger R., Phosphomonoesterase activity with the substrate phenylphosphate. In: Schinner, F., Őhlinger, R., Kandeler, E., Margesin, R., (eds.) Methods in Soil Biology, 1996, pg. 210-213. Springer, Berlin.

Oliveira M.T. and Merwin I.A.2001. Soil physical conditions in a New York orchard after eight years under different groundcover management systems. *Plant and Soil* 234: 233-237

Olsen S.R., Cole C.V., Watanabe F.S. and Dean L. 1954. Estimation of available phosphorus in soil by extraction with sodium carbonate. *USDA, Washington*, p 933

Pascual J.A., Moreno J.L. and Hernandez T. 2002. Persistence of immobilized and total urease and phosphatase activities in a soil amended with organic wastes. *Bioresour. Technol.*, 82: 73–78

Ponnamperuma FN. 1972. The chemistry of submerged soils. *Adv. Agron.* 24, 29-96.

Pooniya V., Shivay Y.S., Rana A., Nain L. and Prasanna R. 2012.Enhancing soil nutrient dynamics and productivity of basmati rice through residue incorporation and zinc fertilization. *Eur J Agron* 41:28–37

Reddy B.N. and Suresh G. 2009. Crop diversification with oilseed crops for maximizing productivity, profitability and resource conservation. *Indian J Argon* 54 (2): 206-214.

Samuel A.D. and Kiss S. 1999. The effects of soil management practices on the enzymatic activities in a brown luvic soil stud. Univ. Babeş- Bolyai, *Biol.*, 44, 1999, pg. 189-19

Serra-Wittling C., Houot S. and Barriuso E.1995. Soil enzymatic response to addition of municipal solid-waste compost. *Biol Ferti Soils* 20: 226-236.

Sharma A.K., Thakur N.P., Koushal Sanjay and Kachroo Dileep. 2007. Profitable and energy efficient rice-based cropping system under subtropical irrigated conditions of Jammu. In: Extended summaries 3rd National Symposium on Integrated Farming Systems, October 26-28, 2007 organized by Farming System and Development Association (Project Directorate for Cropping System Research, Modipuram, Meerut) at Agricultural Research Station, Durgapura, Jaipur.

Sharma B.R. 2002. Efficient conservation and management of water resources for sustainable agriculture. *Indian Farming* 52 (8): 66-70.

Sharma P.K. and De Datta S.K. 1986. Physical properties and processes of puddled rice soils. *Adv. Soil Sci*. 5, 139-178.

Sharma S.K. and Sharma S N. 2005. Effect of crop diversification of rice–wheat cropping system on productivity and profitability. *J Sustain Agric* 26:39–48

Sharma S.N. and Sharma S.K. 2004. Role of crop diversification and integrated nutrient management in resilience of soil fertility under rice–wheat cropping system. *Arch Agro Soil Sci* 50:345–352

Singh G. 2012. Agriculture diversification options for climate resilient agriculture and livelihood securities. In: Proceedings of 3rd international agronomy congress on agricultural diversification, climate change management and livelihoods, vol I. New Delhi, India, pp 19–21

Singh H.P. and Malhotra S.K. 2013. Trend of horticultural research particularly vegetables in India and its regional prospects. pp 321–343. In: Holmer R, Linwattana G, Nath P, Keatinge JDH (eds) Proceedings of regional symposium on high value vegetables in Southeast Asia: production, supply and demand. AVRDCWorld Vegetable Centre, Taiwan. Publication No. 12, pp 758

Singh R. P., Das S. K., Bhaskara Rao V. M. and Narayana Reddy M. 1990. Towards sustainable dryland agricultural practices, pp5-8. Central Research Institute for Dryland Agriculture, Hyderabad.

Singh R.K.,Bohra J.S.,Nath T.,SinghY. and Singh K.2011.Integrated assessment of diversification of rice–wheat cropping system in Indo-Gangetic plain. *Arch Agron Soil Sci* 57:489–506

Snyder D. and Trofymow J.A. 1984. Rapid accurate wet oxidation diffusion procedure for determining organic and inorganic carbon in plant and soil samples. *Comm. Soil Sci*. *Plant Anal*. 15, 1587–1597.

Spedding T.A., Hamel C., Mehuys G.R. and Madramootoo C.A. 2004. Soil microbial dynamics in Maize-growing soil under different tillage and residue management systems. *Soil Biol. Biochem.,* 36: 499–512

Subbiah B.V. and Asija G.L. 1956. A rapid procedure for assessment of available nitrogen in rice soils. *Curr Sci* 25:259–260

Tripathi R.P. 1992. Physical properties and tillage of rice soils in rice–wheat system. In: Pandey, R.K., Dwivedi, B.S., Sharma, A.K. (Eds.), Rice–wheat Cropping System. PDCSR, Modipuram, India, pp. 53–67

Walkley A.J.and Black I.A. 1934. An examination of the Dagtjareff method for determination of soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci* 37: 29–38

Wlodarczyk T., Stepniewski W. and Brzezinska M. 2002. Dehydrogenase activity, redox potential, and emissions of carbon dioxide and nitrous oxide from Cambisols under flooding conditions. *Biol Fert Soils* 36: 200-206.

Yadav J.S.P. 2002. Agricultural resource management in India: the challenges. J Agri Water Manag 1(1):61-69

Yadav R.L. 1998. Factor productivity trends in a rice–wheat cropping system under long -term use of chemical fertilizers. *Exp. Agric*. 34, 1–18.

Yosefi K., Galavi M., Ramrodi M. and Mousavi S.R. 2011. Effect of bio-phosphate and chemical phosphorus fertilizer accompanied with micronutrient foliar application on growth, yield and yield components of maize (Single Cross 704). *Aust J Crop Sci* 5 (2):175-180.

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