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Performance of Diversified Legume Entailing Ultra High Intensity Rice based Cropping System Models for Higher Productivity, Profitability and Sustainability

Monika Menia, B.C. Sharma, A.P. Singh[1], Vivak M. Arya[2], Manish K. Sharma[3], Satesh Kumar[4], Amrish Vaid[5], Vishal Gupta[5], Neetu Sharma

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ABSTRACT

Background: An intensive cropping system involving legume and vegetable crops not only highly productive and profitable but should also be stable over time and maintains soil health in present scenario. So, keeping this point in view the present investigation was carried out to evaluate the productivity, profitability and sustainability of legume entailing different ultra high intensity rice based cropping system models under irrigated sub-tropics.

Methods: The field experiment was conducted at Research Farm, SKUAST-Jammu, Main Campus, Chatha for two consecutive years from *kharif* 2019 to summer season of 2021. The experiment consisting of five legume entailing rice based cropping system models of cropping intensity varying from 300-600% *viz.* T_1: Rice (Basmati-370) - Wheat (HD-3086) - Cowpea (Lobia Super-60) having 300% cropping intensity, T_2: Rice (Basmati-564) - Potato (Kufri Badshah) - Wheat (Raj-3765) - Mixed fodder (Maize+Cowpea+Charri in 2:2:1 ratio) having 400% cropping intensity, T_3: Rice (SJR-129) - Knol khol (G-40) - Potato (Kufri Sindhuri) - Green gram (IPM 02-3) having 400% cropping intensity, T_4: Rice (Pusa-1121) - Radish (CR-45) - Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special) having 500% cropping intensity in relay cropping from fourth crop onwards and T_5: Rice (IET-1410) - Fenugreek (JF-07) - Knol khol (G-40) - Green onion (Nasik Red) - Dry onion (Selection-1) - Black gram (Pant U-19) having 600% cropping intensity in relay cropping from third crop onwards was laid out in a randomized block design with four replications.

Result: The results obtained under two years research study revealed that treatment T_4 recorded significantly highest basmati-370 rice equivalent system productivity followed by treatment T_5 . Further, treatment T_4 also recorded highest system cost of cultivation, system gross returns and system net returns. System soil fertility status in terms of available NPK after completion of second crop cycle was significantly affected. Among different cropping systems, significantly higher available nitrogen and phosphorus were recorded in treatment T_5 system which was at par with treatment T_4.

Key words: Basmati rice, Cropping systems, Productivity, Profitability, Sustainability, System productivity, Ultra high intensity.

INTRODUCTION

Rice (*Oryza sativa* L.) stands first amongst all the food grain crops of the world and is the staple food of more than half of the world's population. Rice-wheat cropping system is the most predominant cropping system in India because of its major contribution in enhancing food grain production. The continuous adoption of rice-wheat cropping system has been responsible for the declining soil fertility, emergence of multiple micronutrients deficiencies, excess emission of greenhouse gases and decline in water table (Todar *et al*., 2018; Shahane and Shivay, 2019). This cropping system is being practiced in 13.50 million hectare across the Indo-Gangetic Plains of South Asia, contributing more than 30% and 40% to the total rice and wheat area, respectively (Gathala *et al*., 2011). In view of the limited scope for horizontal expansion to augment food production, the alternative is to concentrate on vertical growth by increasing the productivity of the available land area. Intensified crop diversification would fulfill the basic needs of cereals, pulses, vegetables as well as fodder and has been recognized as an effective strategy for achieving the objectives of national food security, income growth, poverty alleviation, employment generation, judicious use of land and water

Division of Agronomy, Faculty of Agriculture, SKUAST-Jammu, Chatha-180 009, Jammu and Kashmir, India.
[1]Advanced Centre for Rainfed Agriculture, Rakh Dhiansar, SKUAST, UT-181 133, Jammu and Kashmir, India.
[2]Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, SKUAST-Jammu, Chatha-180 009, Jammu and Kashmir, India.
[3]Division of Statistics and Computer Science, Faculty of Agriculture, SKUAST-Jammu, Chatha-180 009, Jammu and Kashmir, India.
[4]Division of Vegetable Science and Floriculture, Faculty of Agriculture, SKUAST-Jammu, Chatha-180 009, Jammu and Kashmir, India.
[5]Division of Plant Pathology, Faculty of Agriculture, SKUAST-Jammu, Chatha-180 009, Jammu and Kashmir, India.

Corresponding Author: Monika Menia, Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha-180 009, Jammu and Kashmir, India. Email: monikamenia90@gmail.com

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resources, sustainable agricultural and environmental development. In India, more than 80% of farming community belongs to marginal and small farmers having only 32.50% of the total operational area. The income from single season field crop is hardly sufficient to sustain the small farmer's family. The importance of highly intensive crop sequence is well recognized to sustain these farm families and to meet the growing demand of ever increasing population as well. An intensive cropping system should not only be highly productive and profitable but should also be stable over time and maintains soil fertility in present conditions taking care of soil health for future. So, intensification of crops has been envisaged as a new strategy for enhancing and stabilizing productivity.

Introduction of short duration, photo-insensitive, dwarf and input responsive high yielding varieties of vegetables, pulses and fodders in sequence with rice help in achieving the purpose of identification of cropping system models. Pulses are next to cereals in terms of their economic and nutritional importance as human consumption. Pulses are described as "poor men's meat" due to its high protein content (Abbas *et al*., 2011). They contain about double the amount of protein found in wheat and about three times the amount of protein in rice. The Indian Council of Medical Research (ICMR) recommends 40 g pulses man^{-1} day^{-1} (ICMR-NIN, 2011). However, actual availability ranges from 30-35 g pulses man^{-1} day^{-1} (Roy *et al*., 2017). Pulses continued to be an integral component of sustainable crop-production system, as these crops have ability of biological nitrogen fixation, low water requirement and capacity to withstand moisture stress conditions. These are well known for their soil fertility restoration value. Deep-rooting, leaf-shedding ability and mobilization of insoluble soil nutrients, especially phosphorus, are some of the important characteristics of pulses. To arrest the declining trend in productivity of cereal-based cropping systems, inclusion of pulses is an important alternative for improving physical, chemical and biological environment of soil. Now-a-days, vegetables are ideal choice for cash crops since they are easy to raise, provide high yields and command a higher market price than cereals and pulses whereas fodder crop is an integral part of Indian farming which is a blend of both crop and animal components. Hence, the present investigation was carried out to evaluate diversified legume entailing ultra high intensity rice based cropping system models for higher productivity, profitability and sustainability.

MATERIALS AND METHODS

The field experiment was conducted at Research Farm of Division of Agronomy, SKUAST-Jammu, Main Campus, Chatha for two consecutive years from *kharif* 2019 to summer season of 2021. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction and medium in organic carbon, available nitrogen, phosphorus and potassium with electrical conductivity in the safer range. The experiment consisting of five legume entailing rice based cropping system models of cropping intensity varying from 300-600% *viz.* T_1: Rice (Basmati-370) - Wheat (HD-3086) - Cowpea (Lobia Super-60) having 300% cropping intensity, T_2: Rice (Basmati-564) - Potato (Kufri Badshah) - Wheat (Raj-3765) - Mixed fodder (Maize+Cowpea+Charri in 2:2:1 ratio) having 400% cropping intensity, T_3: Rice (SJR-129) - Knol khol (G-40) - Potato (Kufri Sindhuri) - Green gram (IPM-02-3) having 400% cropping intensity, T_4: Rice (Pusa-1121) - Radish (CR-45) - Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special) having 500% cropping intensity in relay cropping from fourth crop onwards and T_5: Rice (IET-1410) - Fenugreek (JF-07) - Knol khol (G-40) - Green onion (Nasik Red) - Dry onion (Selection-1) - Black gram (Pant U-19) having 600% cropping intensity in relay cropping from third crop onwards was laid out in a randomized block design with four replications. Crops taken in different ultra high intensity rice based cropping system models were raised as per their respective recommended package of cultivation except for the nutrient requirement of all the crops in the systems, excluding pulse and vegetable crops, whose nutrient need were met through inorganic and organic sources as per recommendations. Of the total requirement of nitrogen, 25% was supplemented through farm yard manure and 75% through inorganic sources. The inorganic sources for nitrogen, phosphorus and potassium were urea, diammonium phosphate and muriate of potash, respectively. The yield of different crops were converted into basmati-370 rice equivalent yield based on the prevailing market price of different crops. The sale price of basmati-370 rice grain was Rs. 34.00 kg^{-1} and Rs. 44.25 kg^{-1} during 2019-20 and 2020-21, respectively. The basmati-370 rice equivalent yield was calculated by using the following formula:

Basmati-370 rice equivalent yield (kg ha^{-1}) =

$$\text{Economic yield of crop (kg ha}^{-1}\text{)} \times \frac{\text{Price of crop whose yield has to be converted (Rs. kg}^{-1}\text{)}}{\text{Price of basmati-370 rice grains (Rs. kg}^{-1}\text{)}}$$

Basmati-370 rice equivalent system productivity was obtained by adding basmati-370 rice equivalent yields of different crops taken in different cropping systems and was expressed in kg ha^{-1}. System relative economic analysis *viz*. cost of cultivation, gross returns and net returns realized under different legume entailing ultra high intensity rice based cropping systems models were worked out with the help of operating cost's of individual operations/ inputs of crops involved in all cropping systems and sale price of output of the crops. Net returns (Rs. ha^{-1}) were worked out by subtracting the cost of cultivation from the gross returns.

RESULTS AND DISCUSSION

Basmati-370 rice equivalent system productivity

It is evident from the overall mean data (Table 1) that legume entailing ultra high intensity rice based cropping system models had a significant influence on basmati-370 rice equivalent system productivity. Among different cropping systems, treatment T_4: Rice (Pusa-1121) - Radish (CR-45)

- Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special) registered significantly highest basmati-370 rice equivalent system productivity (25058.38 kg ha^{-1}) which was followed by treatment T_5: Rice (IET-1410) - Fenugreek (JF-07) - Knol khol (G-40) - Green onion (Nasik Red) - Dry onion (Selection-1) - Black gram (Pant U-19) (19227.92 kg ha^{-1}). Treatment T_5 was found statistically at par with treatment T_3 (17853.51 kg ha^{-1}) and treatment T_2 (15253.62 kg ha^{-1}) whereas significantly lowest basmati-370 rice equivalent system productivity of 8786.00 kg ha^{-1} was recorded in treatment T_1: Rice (Basmati-370) - Wheat (HD-3086) - Cowpea (Lobia Super-60). This might be ascribed to the higher production potential of vegetable crops such as radish, green onion, french bean, okra, potato and knol khol along with their higher market prices were responsible for obtaining higher system productivity in terms of basmati-370 rice equivalent yield. Kachroo *et al.* (2014) and Tandel *et al.* (2014) reported similar findings in rice based cropping systems.

System profitability

Overall mean data on cost of cultivation (Table 1) reveals that highest system cost of cultivation of Rs. 525119.37 ha^{-1} was incurred with treatment T_4 followed by treatments T_3 (Rs. 389296.67 ha^{-1}), T_5 (Rs. 372301.07 ha^{-1}) and T_2 (Rs. 306424.38 ha^{-1}) while lowest system cost of cultivation (Rs. 123094.59 ha^{-1}) was recorded with treatment T_1. Inclusion of green onion, french bean, okra, knol khol and potato in the cropping systems increased the cost of cultivation due to higher cost of seed/ tuber, manure and fertilizers, as well as high labour requirement for the cultivation of these crops. The results were in close agreement with Sharma *et al.* (2008) who reported that the highest cost of cultivation incurred in rice-potato-onion+maize relay cropping system, followed by rice-potato-onion.

Among different cropping systems, significantly highest system gross returns of Rs. 981512.16 ha^{-1} was recorded with treatment T_4 while treatment T_1 registered significantly lowest system gross returns (Rs. 340598.82 ha^{-1}). Treatment T_4 was followed by treatments T_5 (Rs. 735511.61 ha^{-1}), T_3 (Rs. 684194.80 ha^{-1}) and T_2 (Rs. 588989.14 ha^{-1}). Overall mean data with respect to system net returns given in Table 1 shows that significantly highest system net returns of Rs. 456392.80 ha^{-1} was recorded treatment T_4 followed by treatment T_5 (Rs. 363210.54 ha^{-1}) and T_3 (Rs. 294898.13 ha^{-1}). Further, treatment T_3 was found statistically at par with treatment T_2 (Rs. 282564.76 ha^{-1}) whereas significantly lowest system net returns of Rs. 217504.23 ha^{-1} was recorded with treatment T_1. The highest system gross and net returns might be due to higher basmati-370 rice equivalent yield of vegetable crops such as radish, green onion, french bean, okra, fenugreek and knol khol in the cropping systems which fetched higher market prices, thereby increasing the gross and net returns of cropping systems. These results were in close conformity with the findings of Jat *et al.* (2012) and Yadav *et al.* (2013). Prasad (2016) reported that vegetable based cropping systems showed more gross returns than rice-wheat cropping system. The higher net returns might be due to increasing cropping intensity of the system that enhance the production potential of the cropping systems. Similar results were reported by Mall *et al*. (2014) and Desai *et al*. (2016). Sammauria *et al*. (2020) reported that inclusion of vegetable crops such as onion and fenugreek in cropping systems fetched higher market prices, thus increasing net returns.

Soil fertility

The soil organic carbon is an important factor of soil fertility that plays a crucial role in maintaining sustainability of cropping systems by improving physical, chemical and biological properties of soil. The data with respect to soil organic carbon (Table 2) was not significantly influenced by legume entailing different rice based cropping system models. The soil organic carbon increased from 5.68 to 5.75 g kg^{-1} under all the cropping systems as compared to their initial

Table 1: Effect of legume entailing ultra high intensity rice based cropping system models on basmati-370 rice equivalent system productivity, system cost of cultivation, gross returns and net returns (overall mean data of two years).

Treatments	Basmati-370 rice equivalent system productivity (kg ha^{-1})	System cost of cultivation (Rs. ha^{-1})	System gross returns (Rs. ha^{-1})	System net returns (Rs. ha^{-1})
T_1: Rice (Basmati-370) - Wheat (HD-3086) - Cowpea (Lobia Super-60)	8786.00	123094.59	340598.82	217504.23
T_2: Rice (Basmati-564) - Potato (Kufri Badshah) - Wheat (Raj-3765) - Mixed fodder (Maize+Cowpea+Charri)	15253.62	306424.38	588989.14	282564.76
T_3: Rice (SJR-129) - Knol khol (G-40) - Potato (Kufri Sindhuri) - Green gram (IPM-02-3)	17853.51	389296.67	684194.80	294898.13
T_4: Rice (Pusa-1121) - Radish (CR-45) - Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special)	25058.38	525119.37	981512.16	456392.80
T_5: Rice (IET-1410) - Fenugreek (JF-07) - Knol khol (G-40) - Green onion (Nasik Red) - Dry onion (Selection-1) - Blackgram (Pant U-19)	19227.92	372301.07	735511.61	363210.54
SEm (±)	1687.09	-	10710.87	10710.87
CD (5%)	5198.44	-	33003.48	33003.48

Table 2: Effect of legume entailing ultra high intensity rice based cropping system models on fertility status of soil after completion of second crop cycle.

Treatments	Organic carbon (g kg^{-1})	Initial available N (kg ha^{-1})	Available N (kg ha^{-1})	Initial available P (kg ha^{-1})	Available P (kg ha^{-1})	Initial available K (kg ha^{-1})	Available K (kg ha^{-1})
T_1: Rice (Basmati-370) - Wheat (HD-3086) - Cowpea (Lobia Super-60)	5.68	285.38	294.76	13.37	14.69	130.88	134.63
T_2: Rice (Basmati-564) - Potato (Kufri Badshah) - Wheat (Raj-3765) - Mixed fodder (Maize+Cowpea+Charri)	5.70	289.80	303.22	12.85	14.40	135.23	141.31
T_3: Rice (SJR-129) - Knol khol - (G-40) Potato (Kufri Sindhuri) - Green gram (IPM-02-3)	5.71	286.96	302.39	13.30	14.64	132.15	134.57
T_4: Rice (Pusa-1121) - Radish (CR-45) - Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special)	5.73	291.65	304.51	13.86	14.98	136.10	143.04
T_5: Rice (IET-1410) - Fenugreek (JF-07) - Knol khol (G-40) - Green onion (Nasik Red) - Dry onion (Selection-1) - Black gram (Pant U-19)	5.75	293.84	305.34	13.87	15.41	134.62	137.39
SEm (±)	0.09	1.05	0.73	0.24	0.17	2.01	0.88
CD (5%)	NS	3.24	2.24	NS	0.53	NS	2.73

status. The highest soil organic carbon was recorded in treatment T_5 followed by treatment T_3, T_4 and T_2 whereas the lowest soil organic carbon was recorded with treatment T_1. This might be due to integrated application of inorganic and organic nutrients which attributed to higher contribution of biomass to the soil, accumulation of root residues and leaf shedding resulted in improvement of soil organic carbon over their parental status. Results revealed that significantly higher available nitrogen was recorded with treatment T_5 which was statistically at par with treatments T_4 and T_2 followed by treatment T_3 whereas significantly lowest available nitrogen was registered in treatment T_1. The inclusion of leguminous crops in rice based cropping systems led to addition of nitrogen in the soil through atmospheric nitrogen fixation by root nodules. The findings are in close conformity with those of Upadhyay and Vishwakarma (2014), Lakshmi *et al.* (2015) and Gudadhe *et al.* (2020). Significantly higher available phosphorus was recorded with treatment T_5 which was statistically at par with treatment T_4 while treatment T_2 recorded significantly lowest available phosphorus which was statistically at par with treatments T_3 and T_1. The lowest available phosphorus might be attributed to inclusion of potato crop in treatments T_2 and T_3 which caused lower down of available P in the soil due to heavy mining and utilization of phosphorus by the crop. The organic manures on decomposition, solubilize inorganic and organic phosphorus fractions through release of various organic acids resulting in significant increase in the available phosphorus status of soil (Ninan *et al*., 2013). However, treatment T_4 registered significantly higher available potassium which was found statistically at par with treatment T_2 whereas treatment T_3 recorded significantly lowest available potassium which was statistically at par with treatments T_1 and T_5. This might be due to direct addition of potassium in the accessible K pool in soil and release of potassium owing to organic matter interaction with clay. These results were in close conformity with the findings of Das *et al*. (2004) and Yadav *et al*. (2013). Kumar *et al*. (2012) and Kalhapure *et al*. (2013) reported that cropping systems including legume crops improved the availability of NPK and organic carbon.

CONCLUSION

The results obtained under two years research study revealed that cropping system Rice (Pusa-1121) - Radish (CR-45) - Green onion (Nasik Red) - French bean (Anupama) - Okra (Seli special) having 500% cropping intensity proved to more productive, profitable and remunerative as it can fetched more net returns per unit area. Therefore, farmers with adequate resources can diversify the existing cereal-cereal cropping system with rice based cropping systems diversified with including pulse, vegetable and fodder crops for obtaining higher productivity, profitability and sustainability under irrigated conditions.

Conflict of interest: None.

REFERENCES

Abbas, G., Abbas, Z., Aslam, M., Malik, A.U., Ishaque, M. and Hussain, F. (2011). Effects of organic and inorganic fertilizers on mungbean (*Vigna radiata* L.) yield under arid climate. International Research Journal of Plant Science. 2(4): 94-098.

Das, A., Prasad, M., Shivay, Y.S. and Subha, K.M. (2004). Productivity and sustainability of cotton (*Gossypium hirsutum* L.) wheat (*Triticum aestivum* L.) cropping system as influenced by prilled urea, farmyard manure and Azotobacter. Journal of Agronomy and Crop Science. 190(5): 298-304. doi: http://dx.doi.org/10.1111/j.1439-037X.2004.00110.x.

Desai, L.J., Thanki, J.D., Gudadhe, N.N. and Pankhaniya, R.M. (2016). Sustainable productivity and profitability of diversified rice based cropping system under south Gujarat condition. International Journal of Science, Environment and Technology. 5(3): 1100-1107. http://krishi.icar.gov.in/jspui/handle/123456789/27667.

Gathala, M.K., Ladha, J.K., Kumar, V., Saharawat, Y.S., Kumar, V., Sharma, P.K. and Pathak, H. (2011). Tillage and crop establishment affects sustainability of South Asian rice-wheat system. Agronomy Journal. 103(4): 961-971. doi: http://dx.doi.org/10.2134/agronj2010.0394.

Gudadhe, N.N., Imade, S.R. and Thanki, J.D. (2020). Effect of integrated nutrient management on rice-greengram cropping system. Legume Research-An International Journal. OF: 1-7. https://arccjournals.com/journal/legume-research-an-international-journal/LR-4307.

ICMR-NIN (Indian Council of Medical Research- National Institute of Nutrition). (2011). Dietary Guidelines for Indians-A Manual. Indian Council of Medical Research- National Institute of Nutrition. Available at: https://ninindia.org/DietaryGuidelinesforNINwebsite. Accessed on 09 July, 2019.

Jat, R.A., Dungrani, R.A., Arvadia, M.K. and Sahrawat, K.L. (2012). Diversification of rice (*Oryza sativa*) based cropping systems for higher productivity, resource-use efficiency and economic returns in south Gujarat, India. Archives of Agronomy and Soil Science. 58(4-6): 561-572. doi: https://doi.org/10.1080/03650340.2010.533172.

Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., Sharma, R. and Khajuria, V. (2014). Diversification of rice (*Oryza sativa*) based cropping system for enhancing productivity and employment. Indian Journal of Agronomy. 59(1): 21-25. https://agris.fao.org/agris-search/search. do?record ID = US202100027387.

Kalhapure, A.H., Shete, B.T. and Dhonde, M.B. (2013). Integrated nutrient management in maize (*Zea mays* L.) for increasing production with sustainability. International Journal of Agriculture and Food Science Technology. 4(3): 195-206.

Kumar, A., Tripathi, H.P. and Yadav, R.A. (2012). Intensification and diversification in rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system for sustainability. Indian Journal of Agronomy. 57(4): 319-322.

Lakshmi, C.H., Rao, P.C., Sreelatha, T., Madhavi, M., Padmaja, G. and Rao, P.V. (2015). Residual effect of organic and inorganic nutrient sources on macro and micro nutrient status of *rabi* greengram under rice-greengram cropping system. Legume Research-An International Journal. 38(4): 496-502. doi: http://dx.doi.org/10.5958/0976-0571.2015.00113.7.

Mall, U.S., Manjhi, R.P. and Thakur, R. (2014). Intensification and diversification of rice (*Oryza sativa*) based cropping systems for productivity, profitability and water expense efficiency in Jharkhand. International Journal of Agricultural Sciences. 10(1): 124-129. http://www.researchjournal.co.in/upload/assignments/10_124-129.pdf.

Ninan, J., Sasidharan, N.K., Biji, C., Ambikadevi, D. and Venugopal, V. (2013). Evaluation of organic alternatives to fertilizers for the medicinal rice variety-Njavara. Proceedings of 19th Kerala Environment Congress, 9-11 October 2013, Trivandrum. 299-303. http://cedindia.org/wp-content/uploads/2013/08/KEC-2013.pdf#page=299.

Prasad, D. (2016). Diversification of existing rice-based cropping system for sustainable productivity under assured irrigation condition for Chhattisgarh plains. International Journal of Multidisciplinary Education and Research. 1(3): 85-88. https://www.educationjournal.in/download/45/1-3-48-982.pdf.

Roy, D., Joshi, P.K. and Chandra, R. (2017). Pulses for nutrition in India changing patterns from farm to fork. International Food Policy Research Institute. Washington DC. p256. doi: https://doi.org/10.2499/9780896292567.

Sammauria, R., Meena, O.P., Yadav, M.R., Gupta, K.C., Gupta, A.K. and Yadav, H.L. (2020). Crop diversification of predominant pearl millet based cropping system for higher productivity, resource-use efficiency and profitability in semi-arid Rajasthan. Legume Research-an International Journal. 43(4): 568-572. https://arccjournals.com/journal/legume-research-an-international-journal/LR-4077.

Shahane, A.A. and Shivay, Y.S. (2019). Viable options for diversification of rice in non- conventional rice-conventional wheat cropping system in Indo-Gangetic Plains. International Journal of Bio-resource and Stress Management. 10(4): 352-363. doi: http://dx.doi.org/10.23910/IJBSM/2019.10.4.1979.

Sharma, R.P., Pathak, S.K., Haque, M. and Lal, M. (2008). Productivity, profitability and nutrient balance as influenced by diversification of rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy. 53(2): 97-101. https:/ /agris.fao.org/agris-search/search.do?recordID= IN2009000035.

Tandel, B.M., Patel, N.N. and Tandel, Y.N. (2014). Economic production on rice based vegetable cropping system. Indian Journal of Agronomy. 79: 233-236. https://www.researchgate.net/profile/Yatin-Tandel/publication/331433018-Economic-production-of-rice-based-cropping-system/links/5c791db045851583 1f78b694/Economic-production-of-rice-based-cropping-system.pdf.

Todar, M., Walia, S.S. and Saini, K.S. (2018). Productivity and economics of different cropping systems in relation to tillage, mulching and fertilizer management practices in north-western Indo-Gangetic Plains of India. Indian Journal of Agricultural Sciences. 88(2): 216-221.

Upadhyay, V.B. and Vishwakarma, S.K. (2014). Long term effect of integrated nutrient management in rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy. 59(2): 209-214. https://www.researchgate.net/publication/288540808_Long-term-effect-of-integrated-nutrient-management- in-rice-Oryza sativa-wheat-Triticum-aestivum-cropping-system.

Yadav, S.K., Singh, Y., Yadav, M.K., Babu, S. and Singh, K. (2013). Effect of organic nitrogen sources on yield, nutrient uptake and soil health under rice (*Oryza sativa*) based cropping sequence. Indian Journal of Agricultural Sciences. 83(2): 170-175. https://scholar.google.com/scholar?oi= bibsan dcluster= 1693783287897103925 6andbtnl= 1andhl =en.