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Influence of Crop Diversification in Potato-Based Cropping Sequence on Growth, Productivity and Economics of Potato in Red and Lateritic Soil of West Bengal

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***Abstract*:** Field experiment was conducted at Agricultural farm of the Institute during 2020-21 and 2021-22 to study growth, yield attributes, yield and economics of potato as influenced by potato-based cropping sequences. The experiment, consisted of seven treatments (viz. Potato-sesame; Potato-green gram; Potato-baby corn; Potato-okra; Potato-groundnut; Potato-blackgram and Potato–vegetable cowpea. Potato in potato-groundnut sequence exhibited highest growth, yield attributes (number of tubers hill^{-1} and fresh weight of tubers hill^{-1}) with tuber and haulm yield of 23.95 and 1.30 t ha^{-1}, respectively. Highest gross return, net return and return per rupee investment in potato was also achieved from potato-groundnut sequence (₹ 264 × 10^3 ha^{-1}, ₹ 174 × 10^3 ha^{-1} and 2.91, respectively). These were at par with potato in potato-vegetable cowpea, potato-blackgram and potato–green gram sequences and significantly higher than potato in potato-sesame, potato-baby corn and potato-okra cropping sequences. Inclusion of legume crops in potato-based cropping sequences enhanced tuber and haulm yield of potato resulting in higher return from the sequence.

***Keywords*:** Cropping sequence, Economics, Growth, Potato and yield

The rice-wheat cropping system (RWCS) has been practiced by farmers in Asia and this cropping system is one of the world's largest agricultural production systems, covering an area of 26 million hectares spread over Indo-Gangetic Plains (IGP) in South Asia and China (Singh et al 2019) and is the most important cropping system of India adopted on about 10.5 M ha (Sarkar 2015) and has played a significant role in food security of the country. However, in recent years sustainability of RWCS is adversely affected as yields of both rice and wheat are either stagnant or decreasing due to deterioration of soil health; resurgence of diseases, insects, and weeds; environmental pollution/degradation; decrement in factor productivity or input-use efficiency; increase in cultivation costs and reduction in profit margins (Gautam and Sharma 2004, Gangwar and Prasad 2005, Reddy and Suresh 2009, Chauhan et al 2013). Traditionally, prior to the Green Revolution, agriculture was more diversified and sustainable (Paroda 2019). Scientific advancements and options for improved varieties and new crops led to a shift towards a few crops having potential to yield more and provide a higher income. Such an approach eventually narrowed down dependence to just a few crops like wheat, rice, maize, sugarcane, *etc*. In Green Revolution era (1967-68 to 1977-78), the major focus was on cereals (mainly rice and wheat). Over the years since then, fortunately, food basket has started to diversify again, although more progress still needs to happen.

Crop diversification largely depends on technological innovations aimed at sustainable intensification and increased productivity while reducing the cost of inputs so as to raise the income of farmers. The dynamic aspect of diversification includes the accommodation of new crops or cropping systems that are best suited to prevailing eco-regional conditions while ensuring higher production and income. By growing a variety of crops, farmers lower their risk and can gain access to national and international markets. Agricultural intensification has helped us achieve food security in the past, but now we need to reorient existing cropping systems to be more sustainable and to continue addressing our household food, nutrition, and environmental security. Legume-inclusive production systems can play important roles by delivering multiple services at production-system level, due to the capacity to fix atmospheric nitrogen making them potentially highly suitable for inclusion in low-input cropping systems, and at cropping system levels, as diversification of crops in agroecosystems based on few major species, breaking the cycles of pests and diseases. In India, over the years, the new cropping systems have become predominant in view of their higher productivity as well as income for farmers. Examples are rice-wheat cropping system in the north, groundnut in Gujarat, sugarcane in the north, chickpea in southern states, arhar in the north-western states, soybean in Madhya Pradesh and adjoining states, and winter maize in Bihar. Unfortunately, most of these systems require diversification for greater sustainability and conservation of natural resources. There is need to bring reforms in the existing cropping systems that are more scientifically based and more suited to varying agro-climatic conditions. Diversification of cropping systems is necessary to get higher yield and return, to maintain soil health, preserve environment and meet daily requirement of human and animals (Saha et al 2020). Thus, not only the number of crops but the type of crops included in the cropping sequence are also important and dependence on cereal crops need to be shifted to other food crops like potato, vegetables, root crops, pulse and oil seeds (Samui et al 2004). Hence, an attempt was made to identify suitable cropping sequence for red and lateritic soil of West Bengal with a view to utilize resources judiciously for optimal production levels at reduced costs and with minimum impact on the environment.

MATERIAL AND METHODS

The field experiment was conducted during *rabi* and summer seasons of 2020-21 and 2021-22 at Agricultural farm (23° 39' N latitude, 87° 42' E longitude at an elevation of 58.9 m above mean sea level), Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal. The soil of the experimental site was sandy loam in texture, acidic in nature (pH 5.12), low in organic carbon (0.42%), available nitrogen (140.31 kg N ha^{-1}) and phosphorus (20.14 kg P_2O_5 ha^{-1}) and medium in available potassium (192.67 kg K_2O ha^{-1}) content. The experiment, comprising of seven cropping systems was laid out in randomized block design with three replication (Table 1). The recommended dose of fertilizers (200:150:150 kg of N: P_2O_5:K_2O kg ha^{-1}) was applied in potato where half quantity of total nitrogen, entire P_2O_5 and K_2O was applied as basal. Top dressing of the remaining nitrogen was done at the time of earthing up at 30 DAP (days after planting). Potato (variety Kufri jyoti) was planted on flat beds with a spacing of 50 cm × 25 cm on November 30, during both the years of 2020-21 and 2021-22, and harvested on March 02, during both years, Summer crops viz, sesame (var. Roma), green gram (var. Samrat), baby corn (hybrid hm-4), okra (Hybrid F-1), groundnut (TAG-24), blackgram (Kalindi) and vegetable cowpea (Pusa sukomal) were sown on March 09 and harvested during last week of June and first week of July during 2021 and 2022, respectively. The summer crops were raised as per recommended package of practices for each crop. The biometric observations for different growth parameters and yield attributes of potato were recorded at regular interval. The dry matter accumulation of plant samples was recorded by drying the plant samples in hot air oven at 65° C for 48 hours, till constant weights were obtained. The crop growth rate was calculated as increase in dry matter per unit of land area per unit of time and expressed as (g m^{-2} day^{-1}) .

$$CGR = (W_2 - W_1)/ (t_2 - t_1)$$

Where W_2 and W_1 are the final and initial dry weights at times t_2 and t_1, respectively.

Weight of fresh tubers was taken from randomly selected plants in each plot and the tuber bulking rate (TBR) between 30 to 45, 45 to 60 and 60 to 75 DAP was estimated and expressed as (g m^{-2} day^{-1}) .

$$TBR = (W_2 - W_1)/ (t_2 - t_1)$$

Where W_2 and W_1 are the final and initial fresh weights of tubers per unit area at times t_2 and t_1, respectively.

The tuber growth rate (TGR) was calculated by taking dry weights of potato tubers at 30 to 45, 45 to 60 and 60 to 75 DAP and expressed as (g m^{-2} day^{-1}) .:

$$TGR = (TW_2 - TW_1)/ (t_2 - t_1)$$

Where TW_2 and TW_1 are the final and initial dry weights of tubers per unit area at times t_2 and t_1, respectively.

Table 1. Growth attributes of potato as influenced by crop diversification in potato-based cropping sequences (Pool data for 2 years)

Treatment	Plant height (cm) at harvest	LAI at 60 DAP	Dry matter accumulation (g m^{-2}) at harvest	CGR (g m^{-2} day^{-1}) at 60-75 DAP	TBR (g m^{-2} day^{-1}) at 60-75 DAP	TGR (g m^{-2} day^{-1}) at 60-75 DAP
T_1 - Potato–sesame	83.0	4.57	592.3	10.66	83.53	12.09
T_2 - Potato–green gram	87.4	4.86	652.0	12.08	85.26	13.61
T_3 - Potato–baby corn	82.8	4.56	543.8	9.33	81.71	12.06
T_4 - Potato–okra	82.7	4.48	533.4	9.62	79.07	11.38
T_5 - Potato–groundnut	89.7	5.07	686.8	12.68	88.42	14.93
T_6 - Potato–blackgram	87.4	4.94	665.3	12.24	86.33	13.79
T_7 - Potato–vegetable cowpea	88.0	4.94	654.6	11.78	87.42	15.39
CD (p=0.05)	NS	NS	NS	NS	NS	0.96

RESULTS AND DISCUSSION

Growth attributes of potato: The growth attributes of potato *viz*. plant height, leaf area index, dry matter accumulation, CGR, TBR and TGR at different growth stages were significantly influenced by crop diversification in various potato-based cropping sequences on pooled data basis (Table 1). The highest plant height (89.7 cm at harvest), LAI (5.07 at 60 DAP), dry matter accumulation (686.8 g m^{-2}) and CGR (12.68 g m^{-2} day^{-1} at 60-75 DAP) of potato was observed in potato-groundnut sequence which was at par with potato in potato-vegetable cowpea, potato-blackgram and potato-green gram sequences, but significantly higher when compared to other sequences, *viz*. potato-sesame, potato-baby corn and potato-okra. Higher growth attributes in potato-legume sequences over potato-non legume ones might be attributed to the fact that N fixation occurred in legumes which might have led to higher carryover effect on soil fertility parameters resulted in higher availability and uptake of nutrients by potato crop.

Highest TGR (15.39 g m^{-2} day^{-1}) of potato was observed at 60-75 DAP in potato-vegetable cowpea sequence which was statistically at par with potato-groundnut, potato-blackgram and potato-green gram sequences but significantly higher than potato-non legume cropping sequences during all the growth stages which might be due to higher accumulation of photosynthates into the tubers thus increasing the fresh weight and dry weight of tubers. However, TBR was not influenced significantly by various potato-based cropping sequences The higher growth attributes of potato in potato-legume sequences might be attributed to the 'nitrogen effect' of the associated legume crop through N provision from BNF (Peoples et al 2009). Angus et al (2015) also reported similar results in wheat when it was grown in wheat-legume sequences. Similar results in terms of higher growth attributes in rice was reported by Saha et al (2020).

Yield components and yield of potato: The significant response was found from crop diversification in potato-based cropping sequences on yield components (Table 2) of potato (i.e., number of tubers $hill^{-1}$ and fresh weight of tubers $hill^{-1}$). at harvest. Among different potato-based cropping sequences, highest number of tubers per hill and fresh weight of tubers per hill was in potato-groundnut sequence (6.88 and 312.1 g, respectively) because of the nitrogen effect of the legume crop which resulted in higher number of tubers in potato crop. The significant response was recorded in tuber yield of potato due to inclusion of various crops in potato-based cropping sequences whereas the haulm yield showed no significant response. Tuber yield of potato was significantly higher in potato-groundnut sequence (23.95 t ha^{-1}) due to higher growth parameters and yield components which finally led to higher tuber yield. This was followed by potato-vegetable cowpea (23.67 t ha^{-1}), potato-blackgram (23.64 t ha^{-1}) and potato-green gram (23.51 t ha^{-1}). However, these treatments were at par with each other (Table 2). In terms of tuber yield of potato, potato-sesame, potato-baby corn and potato-okra sequences, were significantly lower when compared to potato-legume-based sequences. Inclusion of legume crops in the sequences might have enhanced the yield components of potato resulting in higher yield when compared with non-legume crops in the sequence. The crop yield after legumes is often enhanced due to combined and interrelated effects of nitrogen provision and non-nitrogen effects (suppressed pest and disease infestation, improved soil properties (Robson et al 2002, Peoples et al 2009 , Ditzler et al 2021) and phosphorus mobilization (Shen et al 2011). Similar results of higher yield associated with the inclusion of legume crops have been reported by Angus et al (2015) and Mukherjee (2016).

Table 2. Yield components, yield and economics of potato as influenced by crop diversification in potato-based cropping sequences (Pool data for 2 years)

Treatment	Number of tubers $hill^{-1}$	Fresh weight (g) of tubers/hill at harvest	Tuber yield (t ha^{-1})	Haulm yield (t ha^{-1})	Gross return (× 10^3 ₹ ha^{-1})	Net return (× 10^3 ₹ ha^{-1})	Return per rupee investment (₹)
T_1	6.17	281.5	22.43	1.20	247	157	2.72
T_2	6.55	291.0	23.51	1.25	259	169	2.85
T_3	6.17	280.4	22.40	1.19	247	156	2.72
T_4	6.16	277.6	22.40	1.19	247	156	2.72
T_5	6.88	297.5	23.95	1.30	264	174	2.91
T_6	6.65	292.8	23.64	1.27	260	170	2.87
T_7	6.65	295.4	23.67	1.29	261	171	2.88
CD (p=0.05)	NS	6.50	0.75	NS	7.74	7.74	0.09

NS - Non-Significant, See Table 1 for treatment details

Economics: The gross return, net return and return per rupee invested in potato were significantly influenced by various potato-based cropping sequences (Table 3). The highest gross return (₹ 264 × 10^3 ha^{-1}), net return (₹ 174 × 10^3 ha^{-1}) and return per rupee investment (₹ 2.91) in potato was under potato-groundnut sequence which was statistically at par with potato-vegetable cowpea, potato-blackgram and potato-green gram sequences. However, these were significantly higher than potato in potato-sesame, potato-baby corn and potato-okra sequences. This could be primarily due to higher yield of potato which was associated with nitrogen effect of legumes under these sequences. Saha et al (2020) also reported similar results in rice when inclusion of legume crops in rice-based cropping systems exerted positive influence in increasing the yield of rice resulting in higher gross return, net return and return per rupee investment. Diversification with high-value crops encouraged the export of farm produce, bringing more profits as mentioned by Singh et al (2019).

CONCLUSION

Potato in potato-groundnut cropping sequence produced higher tuber yield, gross return, net return and return per rupee investment which was statistically at par with potato in potato-vegetable cowpea, potato-blackgram and potato-green gram sequences. Potato-legume-based cropping sequences exhibited significantly higher tuber yield and economic returns over potato-sesame, potato-baby corn and potato-okra sequences.

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