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INTENSIFICATION OF COTTON-WHEAT SYSTEM TO COTTON-POTATO-WHEAT SYSTEM THROUGH INCLUSION OF POTATO IN NORTHWESTERN PLAINS

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SUMMARY

A field experiment was conducted at Project Directorate for Farming Systems Research Modipuram, Meerut during 2005-07 for the evaluation of cotton, potato and wheat genotypes in system mode for intensification and profitability of cotton-wheat system. Highest seed-cotton yield was recorded in LHH 144 (2.5 t ha^{-1}) followed by Ankur 2534 (2.4 t ha^{-1}), while lowest was in CNH 36 (2.0 t ha^{-1}). Seed-cotton yield was highly correlated with biomass (r=0.884), boll numbers harvested (r=0.785) and boll weight (r=0.888) as observed in LHH 144, Ankur 2534 and Ankur 651. Photosynthesis (Pn, µmole m^{-2} s^{-1}) and photosynthetic water use efficiency (PWUE, mmole CO_2 mole^{-1} H_2O) was higher in cotton hybrids (26-28 and 2.7-3.1, respectively) than varieties (24-25 and 2.5-2.6, respectively). Among potato genotypes, Kufri Pukhraj had significantly higher tuber yield and tuber numbers (22.5 t ha^{-1} and 366 x 1000 ha^{-1}, respectively) than Kufri Surya (17.3 t ha^{-1} and 287 x 1000 ha^{-1}, respectively). Tuber dry matter content, on the other hand, was invariably higher in Kufri Surya (20.2%) than Kufri Pukhraj (17.7%). This was due to higher rate of Pn in Kufri Surya (20.0) at all the dates of plantings than Kufri Pukhraj (17.8). Late sowing of wheat by 30 and 45 days after harvest of potato significantly reduced yield (7-22%) as compared to normal sown wheat (5.3 t ha^{-1}). This was largely due to reduction in biomass (11-18%), LAI (4-18%) and shoot length (3-16%). The reduction in yield was more in PBW 343 (22%) than PBW 373 (7-16%). Among different cotton-potato based systems, WEY and net returns (NR) were significantly higher with Ankur 2534 (19.03 t ha^{-1} and 101.7 x 1000 Rs ha^{-1}, respectively) and Ankur 651 (18.94 t ha^{-1} and 101.0 x 1000 Rs ha^{-1}, respectively) cotton hybrids. Similarly in potato, higher WEY and NR were observed with Kufri Pukhraj (19.63 t ha^{-1}, and 108.1 x 1000 Rs ha^{-1}, respectively) than Kufri Surya (17.31 t ha^{-1}, and 85.9 x 1000 Rs ha^{-1}, respectively). The results indicate that early maturing cotton genotypes (Ankur 651, Ankur 2534 and LHH 144) and potato genotypes (Kufri Pukhraj and Kufri Surya) could provide opportunities for further intensification and enhancing net returns of cotton-wheat system by inclusion of potato in northwestern plains in system mode.

***Key words*: Cotton-potato-wheat system, LAI, photosynthesis, photosynthetic water use efficiency, seed cotton yield, tuber yield, wheat equivalent yield**

INTRODUCTION

Cotton is largely grown as mono crop under rainfed conditions. However under irrigated conditions in north India, cotton is grown in double cropping under cotton–wheat system. Area and productivity of cotton-wheat cropping system has declined (Bhandari *et al.* 1998). This is owing to the fact that cotton being a long duration crop

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imposes restriction on its inclusion in a system mode with crops like potato and wheat. With the improvements in production technologies and development of short duration genotypes of cotton and wheat the productivity of cotton-wheat system has been increased (Chittapur 2004, Singh *et al.* 2004, Singh *et al.* 2007b and Singh *et al*. 2011). However, maximum net return from this system is still far below as compared to other cotton based cropping system. The productivity of cotton-wheat system could be further increased with the intensification of this system by introducing potato, a high value commercial crop. Availability of suitable potato genotypes can help in diversification (Kumar *et al.* 2005). Keeping this in view attempts were made to evaluate the early maturing genotypes of cotton and potato in system mode with wheat. This has been done with the explicit aim to enhance the productivity and profitability of existing cotton-wheat system.

MATERIALS AND METHODS

A field experiment was conducted at Project Directorate for Farming Systems Research Modipuram, Meerut during 2005-2007 under collaborative research programme of PDFSR (formerly PDCSR) and CPRI, in RBD with 3 replications to test the suitability and adaptability of cotton, potato and wheat genotypes for cotton-potato-wheat system. Modipuram is located at 29^0. 4' N latitude and 77^0.46' E longitude at 237 m asl. The climate is categorised as hot, dry and semi–arid (subtropical) with moderate summer and severe cold winters. The average annual rainfall is about 800 mm and potential evapo-transpiration of 1600 mm. The soil of the experimental field was typic Ustochrepts, sandy loam, deep and mildly alkaline (pH 8.2) with low to medium fertility (OC– 0.40%, available P_2O_5– 32.5 Kg and K_2O– 125 Kg/ ha). During 2005-06, three cotton genotypes (Ankur 651, CNH 36 and LHH 144), two potato genotypes (Kufri Surya and Kufri Pukhraj) and two wheat genotypes (PBW 343 and PBW 373) were evaluated in system mode under eight cotton-potato-wheat systems against two cotton-wheat systems. Subsequently, during 2006-07 and 2007-08 two new short duration genotypes of cotton (Ankur 2534 and CNH 120) were included and thus, 12 treatments of cotton-potato-wheat systems (T1- Ankur 651–Kufri Surya–PBW 373, T2- Ankur 651–Kufri Pukhraj–PBW 373, T3- Ankur 2534–Kufri Surya–PBW 373, T4- Ankur 2534–Kufri Pukhraj–PBW 373, T5- CNH 36–Kufri Surya–PBW 373, T6- CNH 36–Kufri Pukhraj–PBW 373, T7- CNH 120–Kufri Surya–PBW 373, T8- CNH 120–Kufri Pukhraj–PBW 373, T9- LHH 144–Kufri Surya–PBW 373, T10- LHH 144–Kufri Pukhraj–PBW 373, T11-LHH 144–Kufri Surya–PBW 343 and T12- LHH 144–Kufri Pukhraj–PBW 343) were evaluated against 2 cotton-wheat systems (T13-LHH 144–PBW 373 and T14-LHH 144–PBW 343). Cotton was sown in kharif (May 12-16) and potato was sown after harvesting of cotton in 1st week (1-5) and 3rd week (16-20) of October. Wheat was sown after harvesting of cotton (November 20) and potato (December 21 and January 5). Recommended package of practices for cotton, potato and wheat were adopted. Plant samples were collected for growth studies from 1m-row length in the field, except cotton hybrids where it was taken from 1.8 m row length. Samples were processed in the lab and oven dried at 70^o C for dry weight (dry biomass) observations and estimation of tuber dry matter content. Leaf area was estimated using leaf area meter (Model LI-3100) and LAI was calculated. Photosynthesis rate were measured using portable Photosynthesis System (Model LI-6400). Biomass (on dry weight basis), seed-cotton, grain yield of wheat and tuber yield of potato were recorded. Wheat equivalent yields (WEY) were calculated for all the cropping sequences to compare the yield potential of different systems following Reddy and Reddi (1995). Net returns were also calculated for each crop sequence, keeping in view the inputs used and out put received from a particular system. The value of the output was computed based on the minimum support price as fixed by the Government of India for cotton (varied for varieties and hybrids) and wheat, and prevailing local market-price for potato. While calculating the cost of cultivation, the rental value of land was not taken into account.

RESULTS AND DISCUSSION

Various morpho-physiological parameters including boll weight and seed-cotton yield were recorded (Table 1 and Fig. 1). Significant variations were observed in morpho-physiological parameters (viz. biomass accumulation, LAI, shoot length, numbers of harvested bolls plant^{-1}), boll weight and seed-cotton yield among

Table 1. Seed cotton yield, number of bolls harvested and boll weight of cotton in cotton-potato-wheat system (Different cotton-potato-wheat systems were taken in RBD with three replications).

Treatments (Cropping systems)	Seed cotton yield (t /ha^{-1})	Boll number harvested (plant^{-1})	Boll weight (g boll^{-1})
Cotton (Ankur 651)–Potato–Wheat (PBW 373)	2.29	25.38	3.16
Cotton (Ankur 2534)–Potato–Wheat (PBW 373)	2.44	25.13	3.50
Cotton (CNH 36)–Potato–Wheat (PBW 373)	1.98	21.15	2.62
Cotton (CNH 120)–Potato–Wheat (PBW 373)	2.17	19.00	3.00
Cotton (LHH144)–Potato–Wheat (PBW 373)	2.45	23.45	3.97
Cotton (LHH144)–Potato–Wheat (PBW 343)	2.44	24.28	3.98
Cotton (LHH 144)–Wheat (PBW 373)	2.49	24.67	4.00
Cotton (LHH 144)–Wheat (PBW 343)	2.49	24.77	3.99
CD (P=0.05)	0.14	2.76	0.22

different cotton genotypes (Table 1 and Fig. 1). Seed-cotton yield was significantly higher in LHH 144 (2.50 t ha^{-1}) and Ankur 2534 (2.44 t ha^{-1}) which were statistically at par (CD = 0.14 t ha^{-1}), while it was lowest in CNH 36 (1.98 t ha^{-1}). Correlation studies reveal that seed-cotton yield was positively associated with biomass (r = 0.884*), boll numbers harvested (r = 0.785*) and boll weight (r = 0.888*). Significantly higher biomass was recorded in LHH 144 (256.6 g plant^{-1}), Ankur 2534 (241.0 g plant^{-1}) and Ankur 651 (226.7 g plant^{-1}), CD value being 11.0 g plant^{-1}. Boll numbers were significantly higher in Ankur 651 (25.4 plant^{-1}), Ankur 2534 (25.1

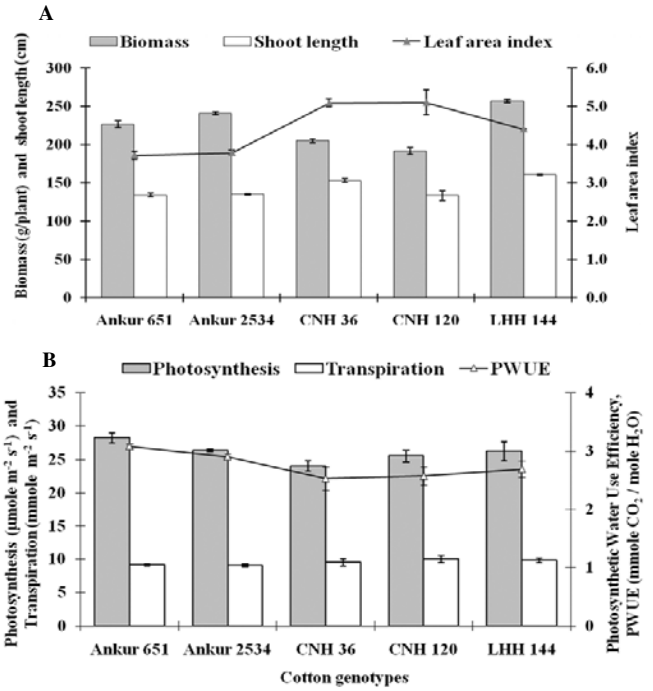

Fig. 1. Genotypic variations in (A.) biomass, shoot length and leaf area index and (B.) photosynthesis, transpiration and photosynthetic water use efficiency (PWUE) in different cotton genotypes (Error bars represent SE ±, where n = 3)

plant^{-1}) and LHH 144 (24.2 plant^{-1}), which were statistically at par (Table 1). However, boll weight was significantly highest in LHH 144 (4.0 g boll^{-1}) followed by Ankur 2534 (3.5 g boll^{-1}) and Ankur 651 (3.2 g boll^{-1}). Significantly, high LAI and low biomass were observed in CNH 36 (5.1 and 204.7 g plant^{-1}) and CNH 120 (5.1 and 191.7 g plant^{-1}), respectively than other genotypes (Fig. 1.A). This was reflected in lower number of harvested bolls in these genotypes (19-21 plant^{-1}). This along with the lower boll weight (2.6 and 3.0 g boll^{-1}, respectively) resulted in low seed-cotton productivity in these genotypes (2.0-2.2 t ha^{-1}) (Table 1). LAI, on the other hand, was negatively associated with biomass (r = -0.391*), boll numbers (r = -0.689*) and seed-cotton yield (r = -0.533*). Photosynthesis rate (μmole CO_2 m^{-2} s^{-1}) and photosynthetic water use efficiency (WUE, mmole CO_2 mole^{-1} H_2O) (Fig. 1.B) were significantly higher (26.2-28.2 and 2.7-3.1, respectively) in hybrids (Ankur 651, Ankur 2534 and LHH 144) than varieties (24.0-25.5 and 2.5-2.6, respectively). The above results also get support from our earlier studies (Singh *et al.* 2004 and Singh *et al.* 2007a).

Table 2. Shoot length, leaf area index and biomass at 45 and 65 days after planting (DAP) in potato cultivar Kufri Pukhraj and Kufri Surya grown as short duration (70 days) early crop in between cotton and wheat at Modipuram (Different cotton-potato-wheat systems were taken in RBD with three replications).

Treatment (Cropping systems)	Crop growth status at 45 DAP								
	Shoot length (cm/plant)			LAI			Total Biomass (t/ha)		
	K Surya	K Pukhraj	Mean	K Surya	K Pukhraj	Mean	K Surya	K Pukhraj	Mean
Cotton (Ankur 651)–Potato – Wheat (PBW 373)	51.3	57.7	54.5	1.16	1.36	1.26	2.26	2.60	2.43
Cotton (Ankur 2534)–Potato – Wheat (PBW 373)	53.0	55.9	54.5	1.24	1.49	1.37	2.19	2.75	2.47
Cotton (CNH 36)–Potato – Wheat (PBW 373)	52.4	56.3	54.3	1.31	1.98	1.65	2.30	2.77	2.54
Cotton (CNH 120)–Potato –Wheat (PBW 373)	52.3	57.3	54.8	1.49	1.42	1.45	2.71	3.26	2.98
Cotton (LHH 144)–Potato – Wheat (PBW 373)	52.3	56.7	54.5	1.41	1.69	1.55	2.12	2.70	2.41
Cotton (LHH 144)–Potato – Wheat (PBW 343)	53.0	56.3	54.7	1.54	1.54	1.54	1.93	2.36	2.14
Mean	52.4	56.7	—	1.36	1.58	—	2.25	2.74	—
CD (5%) : Cotton geno, Potato geno & Interaction	2.9, 1.7 & 4.2			NS, 0.17 & NS			0.24, 0.14 & NS		
	Crop growth status at 65 DAP								
Cotton (Ankur 651)–Potato – Wheat (PBW 373)	58.1	64.4	61.3	1.64	2.15	1.90	4.56	6.12	5.34
Cotton (Ankur 2534)–Potato – Wheat (PBW 373)	57.7	65.3	61.5	1.75	2.09	1.92	5.01	5.58	5.29
Cotton (CNH 36)–Potato – Wheat (PBW 373)	58.3	58.3	58.3	1.66	2.00	1.83	4.27	4.57	4.42
Cotton (CNH 120)–Potato –Wheat (PBW 373)	57.7	61.3	59.5	1.68	1.67	1.67	4.42	5.90	5.16
Cotton (LHH 144)–Potato – Wheat (PBW 373)	57.3	65.7	61.5	1.56	1.89	1.73	4.11	4.06	4.09
Cotton (LHH 144)–Potato – Wheat (PBW 343)	53.0	62.3	57.7	1.62	2.04	1.83	3.78	4.23	4.01
Mean	57.0	62.9	—	1.65	1.97	—	4.36	5.08	—
CD (5%) : Cotton geno, Potato geno & Interaction	NS, 2.51 & NS			NS, 0.18 & NS			0.55, 0.32 & 0.78		

Potato genotypes, Kufri Pukhraj and Kufri Surya were sown every year after the harvest of cotton either in the beginning or/and in mid October. Crop growth parameters indicated that mean shoot length was lower (52.4 cm) in Kufri Surya than in Kufri Pukhraj (56.7 cm) at 45 DAP (Table 2). Controlled shoot height is beneficial as excessive shoot growth early in the season is considered prohibitive for good yield formation in potato crop (Struik 2007). The September planted crops are exposed to warm climate and long sunshine hours that is known to accumulate higher GA and make the shoots lengthy and lanky (Basu and Minhas, 1999). Kufri Surya, also known as the first ever heat tolerant genotype maintained shoots height lower than K. Pukhraj at 65 DAP also (Table 2). On the other hand, K. Pukhraj invested more food in the above ground canopy and it had higher LAI (1.58) as well as biomass productivity (2.74 t ha^{-1}) as compared to Kufri Surya (1.36 and 2.25 t ha^{-1}, respectively). The trend in crop growth was similar at 65 days (Table 2). Visibly Kufri Surya had more compact crop canopy and it had higher PRUE and WUE than Kufri Pukhraj in spite of higher transpiration rate (Fig. 2.A). Tuber yield and tuber numbers were significantly higher in Kufri Pukhraj (22.5 t ha^{-1} and 366 x 1000 ha^{-1}, respectively) than Kufri Surya (17.3 t ha^{-1} and 287 x 1000 ha^{-1}, respectively). Tuber dry matter content, on the other hand, was invariably higher in Kufri Surya (20.2%) than Kufri Pukhraj (17.7%) (Fig. 2.B). This was due to higher rate of photosynthesis in Kufri Surya (20.0 µmole CO_2 m^{-2} s^{-1}) on all dates of plantings than Kufri Pukhraj (17.8 µmole CO_2 m^{-2} s^{-1}). Higher tuber yield of Kufri Pukhraj was largely due to higher tuber numbers and total biomass produced, owing to high LAI in this genotype than Kufri Surya, as also reported by Singh *et al.* (2007 a). Potato yield of about 17 t ha^{-1} with 20% tuber dry matter in Kufri Surya and about 23 t ha^{-1} with 18% tuber dry matter in Kufri Pukhraj was achieved in 70 days. Though, potatoes having 20% tuber dry matter from Kufri Surya are known to fetch premium prices, as these were also suitable for processing (Kumar *et al.* 2003).

Variations in different growth and physiological parameters (biomass, LAI, shoot length, photosynthesis and PWUE) and grain yield of wheat under different treatments were significant (Table 3 & Fig. 3).

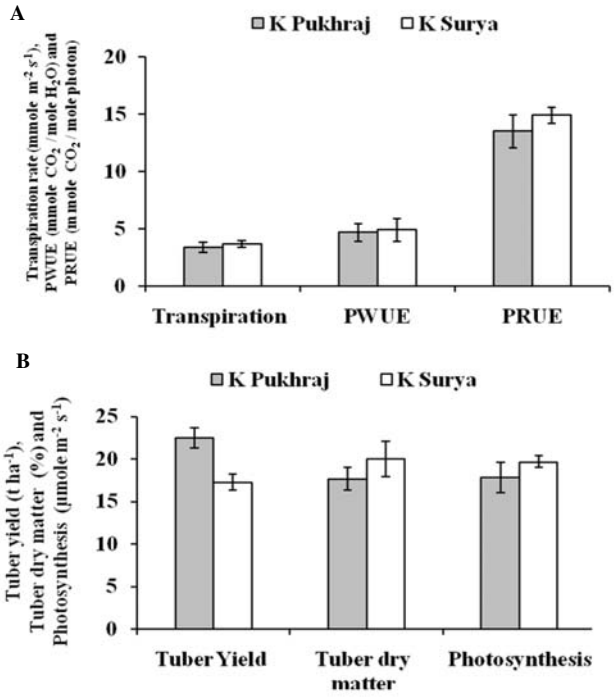

Fig. 2. (A.) Transpiration rate, photosynthetic water use efficiency (PWUE), photosynthetic radiation use efficiency (PRUE) and (B.) Tuber yield, tuber dry matter content and photosynthesis rate in potato cultivar Kufri Pukhraj and Kufri Surya grown as short duration (70 days) early crop in between cotton and wheat (Error bars represent SE ±, where n = 3)

Treatment differences in number of tillers m^{-2} were not significant. Late planting of wheat 30 and 45 days after normal (DAN), after the harvest of potato, significantly reduced the grain yield (7-22%) as compared with the normal planting of wheat (5.3 t ha^{-1}). Grain yield was more reduced in PBW 343 (22%) than PBW 373 (7-16%) as compared with the normal planting (5.5 and 5.0 t ha^{-1}, respectively). This was due to reduction in biomass (11-18%), leaf area (4-18%) and shoot length (3-16%). Similar results were reported in our earlier studies (Singh *et al.* 2007a). Significant reduction in physiological parameters, *viz* photosynthesis (3-18%), PWUE (25-50%) and PRUE (7-42%), was observed with the late sowing of wheat at grain development stage in both the genotypes (PBW 373 and PBW 343). However, reduction in all these parameters was more in PBW 343 than PBW 373. Significant variations were also observed in overall system's productivity, in terms of wheat equivalent yield (WEY) and net returns (Table 4). These were significantly higher in cotton-potato-wheat systems

Table 3. Grain yield and various morpho-physiological parameters of wheat in cotton-potato-wheat system (Different cotton-potato-wheat systems were taken in RBD with three replications).

Treatments	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	Leaf area index	Shoot length (cm)	Tillers (m^{-2})
Cotton (Ankur 651)–Potato–Wheat (PBW 373)	4.75	10.95	5.03	93.0	538
Cotton (Ankur 2534)–Potato–Wheat (PBW 373)	4.56	10.71	5.73	91.7	529
Cotton (CNH 36)–Potato–Wheat (PBW 373)	4.38	10.57	4.41	83.4	543
Cotton (CNH 120)–Potato–Wheat (PBW 373)	4.29	9.90	5.22	80.9	536
Cotton (LHH144)–Potato–Wheat (PBW 373)	4.34	10.22	4.33	81.3	544
Cotton (LHH144)–Potato–Wheat (PBW 343)	4.34	10.25	4.38	81.2	542
Cotton (LHH 144)–Wheat (PBW 373)	5.02	12.11	5.16	95.5	531
Cotton (LHH 144)–Wheat (PBW 343)	5.53	12.50	5.68	97.9	555
CD (P=0.05)	0.228	0.469	0.314	2.913	NS

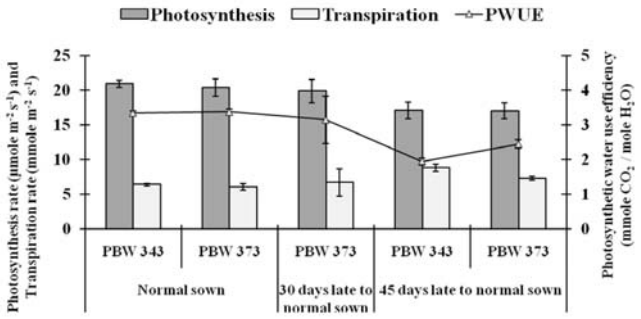

Fig. 3. Photosynthesis rate, transpiration rate and photosynthetic water use efficiency (PWUE) in wheat grown after harvesting of potato in cotton-potato-wheat system (Error bars represent SE ±, where n = 3 for normal sown PBW 373 and PBW 343, n = 12 for wheat 30 days late sown PBW 373, n = 6 for wheat 45 days late sown PBW 343 and n = 18 for wheat 45 days late sown PBW 373)

(72% and 50%, respectively) as compared with cotton-wheat (10.72 t ha^{-1}, and 64.5 x 1000 Rs ha^{-1}, respectively). Among different cotton-potato based systems, WEY and net returns were significantly higher (Table 4) with Ankur 2534 (19.03 t ha^{-1}, and 101.7 x 1000 Rs ha^{-1}, respectively) and Ankur 6514 (18.94 t ha^{-1}, and 101.0 x 1000 Rs ha^{-1}, respectively) cotton hybrids. Similarly in potato, higher WEY and net returns were observed with Kufri Pukhraj (19.63 t ha^{-1}, and

Table 4. Wheat yield equivalent (WEY) and net return of cotton-potato-wheat system (Different cotton-potato-wheat systems were taken in RBD with three replications).

Treatments	WEY (t ha^{-1})	Net return (Rs. ha^{-1})
Cotton (LHH 144)–Wheat (PBW 373)	10.38	61387
Cotton (LHH 144)–Wheat (PBW 343)	11.06	67682
Cotton–Potato (K Surya)–Wheat	17.31	85869
Cotton– Potato (K Pukhraj)–Wheat	19.63	108101
Cotton (Ankur 651)–Potato)–Wheat (PBW 373)	18.94	100983
Cotton (Ankur 2534)–Potato–Wheat (PBW 373)	19.03	101735
Cotton (CNH 36)–Potato–Wheat (PBW 373)	17.77	92291
Cotton (CNH 120)–Potato–Wheat (PBW 373)	18.37	97572
Cotton (LHH 144)–Potato–Wheat (PBW 373)	18.37	94685
Cotton (LHH 144)–Potato–Wheat (PBW 343)	18.35	94644
CD (P=0.05)	0.89	8308

108.1 x 1000 Rs ha^{-1}, respectively) than Kufri Surya (17.31 t ha^{-1}, and 85.9 x 1000 Rs ha^{-1}, respectively). The results indicate that early maturing cotton genotypes (Ankur 651, Ankur 2534 and LHH 144) and potato genotypes (Kufri Pukhraj and Kufri Surya) could provide opportunities for the intensification of cotton-wheat system by inclusion of potato in northwestern plains in system mode.

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