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Effect of Haulm Cutting, Size of Seed Tubers/Seed Pieces and Intra-Row Spacings on Tuber Yield and Economics of Potato Production

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ABSTRACT

The field experiments were conducted during two consecutive *rabi* seasons (October – February) during 2019–20 and 2020–21 at ICAR-Central Potato Research Institute Regional Station, Gwalior, Madhya Pradesh, India located in west central plains of India. Highest emergence of potato plants was recorded with the planting of 40 g whole tubers. Growth attributes *viz*. plant height (58.6 cm) and number of compound leaves (56.7) were recorded highest with 40 g seed piece/whole tuber. Planting of 120 g seed tubers, 10 cm intra row spacing and 114 days haulm cut recorded highest number of small tubers i.e. 3,43,000 ha^{-1}, 3,07,000 ha^{-1} and 3,26,000 ha^{-1}, respectively. Highest total number of tubers was recorded at 114 DAP haulm cut (9,08,000 ha^{-1}), planting of 120 g seed tubers (9,62,000 ha^{-1}) and 10 cm intra row spacing (8,53,000 ha^{-1}). Highest total tuber yield was recorded with 114 DAP haulm cut (59.1 t ha^{-1}), 120 g planted seed tubers (55.5 t ha^{-1}) and 20 cm intra row spacing (49.7 t ha^{-1}). Highest cost of cultivation was recorded with the use of 120 g seed (₹ 386483 ha^{-1}) and intra row spacing of 10 cm ₹ 264261 ha^{-1}. Highest net return (₹ 364084 ha^{-1}) was recorded with 114 DAP haulm cut, planting with 40g seed size tubers (₹ 329822 ha^{-1}) and intra row spacing of 20 cm (₹ 322499 ha^{-1}). Highest benefit-cost ratio was recorded with 114 DAP haulm cut (2.6) planting with 20 g seed size tubers (3.3) and intra row spacing of 20 cm (2.8).

KEYWORDS: Seed tubers/seed pieces, spacings, haulm cuttings, Kufri Mohan, potato

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1. INTRODUCTION

The current global production of potato is around 370.4 million mt and China being the biggest producer globally, India ranks 2nd in area and production of potato in the world after China which contribute 13% of world potato production in 2019 (Anonymous, 2021). In India potato production is mainly confined to Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Assam and Haryana. In India, it is grown on an area of 2.05 mha with the production of 48.66 mt and the productivity is 23670 kg ha^{-1} (Anonymous, 2020).

Healthy seed is the foundation of a high-quality crop and high marketable yield. Growers strive to produce a complete stand of uniform plants with the potential for high yield and quality. That requires quality seed. Potato is usually propagated through seed tubers. Since seed (tuber) is the costliest input and accounts for about 40% of the production cost (Betata et al., 2020, Singh et al., 2019), farmers use either small whole tubers or cut the big tubers into pieces for planting. Generally, seed treatment with fungicides is done after the tubers are cut longitudinally with each piece containing 2–3 eyes (Kumar et al., 2013). Manipulation of the size of seed tuber piece is considered as a management tool for profitable potato farming (Rykbost and Locke, 1999). To exploit the production potential and benefit from potato crop appropriate manipulation of the production practices such as spacing, seed size, planting depth and nutrient management is essential (Kumar et al., 2009). Planting geometry and types of seed tubers are among the major factors affecting the production, cost of cultivation and productivity of potato (Lung'aho et al 2007; Dawinder et al., 2020). Size of seed tubers and planting geometry determine the quantum of seed for a unit area (Singh and Kushwah, 2010). Effect of dehaulming is significantly found in the yield of seed tuber, the post-harvest quality of potato tuber and the disease, pest protection aspect of plants (Upadhyay and Bashyal, 2020). Availability of 40–50 g tubers for planting is problem as it constitutes 20–25% of total seed production. Farmers have option either use higher seed rate or optimize seed rate by cutting seed tubers.

Seed size and number of eyes per tuber affects plant growth, marketable and tuber yield (Nolte et al., 2003; Dagne et al., 2018). Generally, 20–40 g seed tubers are planted as whole and big tubers of 50 g or more weight are cut into two or more pieces before planting. Since number of eyes per tuber has a direct relationship with surface area, big size seed tubers generally produce more shoots per plant and ultimately leading to higher yield. Use of cut tubers by farmers helps in reducing the amount of seed tuber required and there by the seed cost especially in high bulking varieties (Sahu et al., 2022). Keeping in view limited availability of less than 50 g tubers, the experiment was carried out with potato variety Kufri Mohan which generally produce large size tubers. Higher total yields are generally associated with larger seed pieces, but at some point, the seed piece size will not result in increased yield. A good rule is to keep the number of cut surfaces per tuber to a minimum. Factor combinations of days to haulm cut and row spacing along with size of seed tubers/pieces plays important role in grade wise and total yield potential of a variety (Sadawarti et al., 2017). Keeping above points in view, a field experiment was planned to evaluate date of haulm cutting, different size of cut and whole seed tubers and intra row spacing.

2. MATERIALS AND METHODS

Field experiments were conducted during two consecutive *rabi* seasons (October–February) 2019–20 and 2020–21 at ICAR-Central Potato Research Institute Regional Station, Gwalior MP which is located in west central plains. This location is characterized by (26° N and 78°E and 207 m above mean sea level) and temperature regime of 2.8°C minimum and 45°C maximum, and total average rainfall of 700–800 mm during the years. Soil pH 7.2, EC 0.32 dS m^{-1}, organic carbon 0.23%, available N, P and K 155 (low), 23.07 (high) and 340 (medium) kg ha^{-1}, respectively. Nutrients Cu, Zn and Fe contents in soil were 0.9, 1.1 and 15.8 ppm, respectively. Before beginning of this experiment, previous cropping history of the experimental field was dhaincha (*Sesbania bispinosa*) green manure-potato sequence for 4–5 years.

Seed of variety Kufri Mohan was used in this experiment. Tubers of four weight classes of 20 g, 40 g, 80 g and 120 g seed sizes and 20 g and 40 g cut pieces were used for planting. Two intra row spacing of 10 cm and 20 cm were used for planting. Haulms were cut at two dates *viz* 90 and 114 DAP (days after planting). During seed cutting, care was taken to make sure that the each piece has at least two eyes. Whole tubers of 20 g, 40 g, 80 g, 120 g and cut tuber pieces of two weight classes 20 g, and 40 g, respectively, were planted at 60×20 cm^2 in 4.2×4.0 m^2 plots. The experiment was laid down in split plot design with four replicates. Planting was done on 26th October. All agronomic practices were carried out according to the recommendations for the region. Number of tubers emerged and stems/plant were recorded at 30 and 60 days after planting, respectively. Earthing up was done on 25th November. Recommended dose of N, P_2O_5 and K_2O were 180 kg, 80 kg and 120 kg ha^{-1}, respectively. Full doses of P_2O_5 and K_2O and half dose of N were applied at the time of planting and remaining half dose of N was applied at the time of earthing up. Two applications of fungicide Dithane M 45 and insecticide Imidacloprid were done in the last week of December and second week of January. Five irrigations were applied in 90 days haulm cut crop and six irrigations were applied in 114 DAP haulm cut crop. Haulm cutting of 90 and 114 DAP crop were done on 27.1.2020/21 and 21.2.2020/21, respectively. Potato was harvested on 5.2.2021 and 28.2.2021; respectively in 90 and 114 DAP haulm cut crops. After 15–20 days of curing of potatoes graded tuber number and yields were recorded. Economics were computed using prevailing market prices for inputs and outputs such as tuber (₹ 10000 t^{-1}), and seed cost (₹ 20000 t^{-1}). Yield parameters, number of tubers and tuber fresh weight in size groups of 0–25 g, 25–50 g, 50–75 g, >75 g and total yields were recorded. Data analysis was done using Opstat HAU computer package.

3. RESULTS AND DISCUSSION

3.1. *Growth attributes*

Highest tuber emergence of potato was recorded under 40g whole tuber (95.5%) planted treatment which was significantly higher than 80 and 120 g whole tubers. Emergence was almost same under 20 and 40 g whole and cut tubers. Ebrahim et al., 2018 reported that this may be due to the fact that large tubers had sufficiently more stored reserve food compared to smaller seed tubers to provide an optimal supply of carbohydrate for the emerging seedling of the larger tuber. 10 and 20 cm intra row spacing did not show any significant effect on tuber emergence. Number of stem plant^{-1} was neither affected by seed size nor by cutting of seed tubers. Ebrahim et al., 2018 also reported that this is probably due to a number of sprouts observed in variety during emergence that might have resulted from its genetic potential for sprouting capacity. Intra row spacing also did not show any significant effect on number of stems plant^{-1} (Table 1). Nxumalo et al., 2020 also reported similar findings. Intra row spacing also did not show any significant effect on number of compound leaves plant^{-1}. Similar finding were observed by Sadawarti et al., 2017. Highest number of compound leaves plant^{-1} (56.7) was recorded with 40 g cut seed tubers which was significantly higher than 20 g whole tubers (44.7) and 80 g whole tubers (43.9). Intra row spacings did not show any significant effect on number of compound leaves. Highest plant height was recorded with 40g cut seed tubers (58.6 cm) which was significantly higher than all other seed sizes/cuttings however, it was lowest with 80g whole tubers (51.6cm) followed by 20 g whole tubers (53.7 cm). Ebrahim et al., 2018 reported that shortest plants were recorded from small tuber sizes (25–34 mm) of the local variety (Kellacho). However, small seed tubers from improved varieties (Gudenie and Jalene) did not show a statically significant difference for plant height.

3.2. *Yield attributes (tuber numbers)*

Date of haulm cuttings showed significant effect on number of tubers. Highest number of <25 g tubers were recorded with 114 DAP (3, 26,000 ha^{-1}) which was significantly higher than 90 DAP (2, 61,000 ha^{-1}). Highest number of <25 g tubers were recorded with the planting of 120 g whole tubers (3,43,000 ha^{-1}) which was significantly higher than all other seed sizes except 40 g whole tubers however, lowest number was recorded with 40 g cut tubers (2,65,000 ha^{-1}). Singh and Kushwah (2010) found that bulking rate can be reduced either by increasing number of tubers per unit area or by reducing bulking period.

Highest number of <25 g tubers was recorded with 10 cm intra row spacing (3, 07,000 ha^{-1}) which was significantly higher than 20 cm intra row spacing (2, 79,000 ha^{-1}). Significantly higher number of 25–50 g tubers were recorded at 90 DAP haulm cut (2,33,000 ha^{-1}) compared to 114 DAP. Highest number of 25–50 g tubers were recorded with the planting of 80g whole tubers (2, 60,000 ha^{-1}) which was significantly higher than 20 g whole tubers (2, 20,000 ha^{-1}), 20 g cut tubers (1, 68,000 ha^{-1}) and 40 g cut tubers (1, 63,000 ha^{-1}). Highest number of 25–50 g tubers was recorded with 10 cm intra row spacing (2,23,000 ha^{-1}) which was statistically same with 20 cm intra row spacing (2, 16,000 ha^{-1}). Highest number of 50–75 g tubers were recorded at 114 DAP (1,73,000 ha^{-1}) than 90 DAP (1,36,000 ha^{-1}). Planting of 120 g whole tubers recoded highest number (1,88,000 ha^{-1}) of 50–75 g tubers which was statistically same with 40 and 80g whole tubers. Intra row spacing did not exert any significant effect on number of 50–75 g tubers (Table 2). Highest number of >75 g tubers were recorded with 114 DAP haulm cut (2, 03,000 ha^{-1}) compared to 90 DAP haulm cut (1,28,000 ha^{-1}). Intra row spacing did not show any significant effect on number of >75 g tubers. Significantly highest total tuber number was recorded with 114 DAP haulm cut (9,08,000 ha^{-1}) compared to 7,58 ,000 ha^{-1} with 90 DAP haulm cut. Planting of 120 g seed tubers recorded highest total tubers (962 thousand ha^{-1}) which was significantly higher than 20 g whole tubers (7,99,000 ha^{-1}), 20 g cut tubers (7,20,000 ha^{-1}) and 40 g cut tubers (7,17 ,000 ha^{-1}). Higher total tuber number was recorded with 10 cm intra row spacing which was statistically same with 20cm intra row spacing. Singh and Kushwah (2010) and Kushwah and Singh (2008) also recorded similar results. Narrower distance increases undersize and small tubers (Akasa et al., 2014; Sadawarti et al., 2017).

3.3. *Yield of tubers (weight)*

Date of haulm cuttings showed significant effect on yield of tubers. Highest yield of tubers of <25g was recorded with 90 DAP (5.2 t ha^{-1}) which was significantly higher than 114 DAP (3.4 t ha^{-1}). Highest yield (5.4 t ha^{-1}) of <25 g tubers were recorded with the planting of 120 g whole tubers which was significantly higher than 20 g whole, 20 g cut and 40 g cut tubers. Intra row spacing did not show

Table 1: Effect of type of seed, intra row spacing and days of haulm cutting on growth and yield attributes of potato

Treatments	Emergence %	Stem plant^{-1}	Compound leaves plant^{-1}	Plant height (cm)	Number '000 ha^{-1}				
					<25 g	25–50 g	50–75 g	>75 g	Total
Haulm cutting (A)									
90 DAP	91.9	3.4	49.7	56.2	261	233	136	128	758
114 DAP	91.8	3.3	52.0	53.2	326	206	173	203	908
SEm±	0.52	0.05	0.86	0.83	5.8	3.4	4.8	2.9	9.4
CD (p=0.05)	NS	NS	NS	NS	35.6	20.9	29.6	18.2	57.8
Size and type of seed (B)									
20 g whole	92.9	3.2	44.7	53.7	284	220	141	154	799
40 g whole	95.5	3.6	52.3	54.9	305	253	171	176	905
80 g whole	87.9	3.0	43.9	51.6	293	260	166	173	892
120 g whole	88.9	3.3	53.8	54.6	343	252	188	179	962
20 g cut	92.9	3.4	53.6	54.9	270	168	135	147	720
40 g cut	92.9	3.5	56.7	58.6	265	163	125	164	717
SEm±	1	0.14	1.9	1.1	14.5	11.7	11.6	12.2	31.3
CD (p=0.05)	3.1	NS	5.6	3.2	42.7	34.5	34.2	NS	92.3
Interaction A×B									
SEm±	1.4	0.2	2.7	1.5	20.5	16.5	16.4	17.2	44.2
CD (p=0.05)	4.3	0.6	8.0	4.6	NS	NS	NS	NS	NS
Intra row spacing (C)									
10 cm	91.3	3.3	48.4	55.4	307	223	156	167	853
20 cm	92.4	3.4	53.3	54.1	279	216	153	164	812
SEm±	0.81	0.1	1.7	1.4	12.5	12.8	6	6.1	25.7
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions A×C									
SEm±	1.1	0.14	2.5	1.9	17.6	18.1	8.5	8.6	36.4
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	1.9	0.25	4.3	3.3	30.6	31.4	14.7	14.8	63
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	2.8	0.37	6.1	4.7	43.3	44.5	20.9	20.9	89
CD (p=0.05)	NS				NS	NS	NS	NS	NS

DAP: Days of haulm cut

any significant effect on yield of <25 g tubers. Significantly higher yield of 25–50 g tubers were recorded at 90 DAP haulm cut (11.4 t ha^{-1}) compared to 114 DAP haulm cut (7.3 t ha^{-1}). Highest tuber yield of 25–50 g tubers were recorded with the planting of 80g whole tubers (11.4 t ha^{-1}) which was significantly higher than 20 g whole tubers (9.2 t ha^{-1}), 20 g cut tubers (6.6 t ha^{-1}) and 40 g cut tubers (7.5 t ha^{-1}). Highest yield of 25–50 g tubers was recorded with 10 cm intra row spacing (9.5 t ha^{-1}) which was statistically same with 20 cm intra row spacing (9.2 t ha^{-1}). Highest yield of 50–75 g tubers were recorded at 90 DAP haulm cut (20.2 t ha^{-1}) than 114 DAP haulm cut (13.3 t ha^{-1}). Different seed sizes/cut pieces and intra row spacing did not show any significant effect on yield of 50–75g tubers. Highest yield of >75 g tubers were recorded with 114 DAP haulm cut (35.1 t ha^{-1}) compared to 90 DAP haulm cut (2.2 t ha^{-1}). Highest large size tuber yield was recorded with 120 g whole tubers (21.2 t ha^{-1}) which was significantly higher than 20 g whole and 20 g cut tubers. Intra row spacing did not show any significant effect on yield of >75 g tubers.

Table 2: Effect of type of seed, intra row spacing and days of haulm cutting on yield and economics of potato production

Treatments	Tuber yield (t ha^{-1})					Economics				Yield (t ha^{-1})			
	<25 g	25–50 g	50–75 g	>75 g	Total	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	NR (₹ ha^{-1})	B:C	Fresh haulm	Dry haulm	Dry tuber	WUE (kg ha^{-1} mm)
Days of haulm cutting (A)													
90 DAP	5.2	11.4	20.2	2.2	39.0	213057	389807	176750	1.8	36.7	3.2	6.3	111
114 DAP	3.4	7.3	13.3	35.1	59.1	226577	590661	364084	2.6	20.9	2.4	10.2	147
SEm±	0.09	0.13	0.26	0.69	0.7	10.1	7264	7273	0.1	0.22	0.05	0.21	2.2
CD (p=0.05)	0.53	0.82	1.6	4.2	4.5	54.6	44819	44873	0.3	1.4	0.31	1.3	13.6
Size and type of seed (B)													
20 g whole	3.6	9.2	15.9	16.9	45.6	136483	456169	319686	3.3	27.8	2.8	7.6	120
40 g whole	4.8	10.5	16.6	19.7	51.6	186483	516305	329822	2.8	30.2	2.9	8.4	136
80 g whole	4.8	11.4	18.7	18.3	53.2	286483	532530	246047	1.9	30.8	2.9	9.0	140
120 g whole	5.4	10.8	18.1	21.2	55.5	386483	555346	168863	1.4	32.01	3.1	8.9	146
20 g cut	3.6	6.6	15.3	17.2	42.7	136483	426886	290403	3.1	25.9	2.7	7.2	112
40 g cut	3.5	7.5	15.8	18.6	45.4	186483	454167	267684	2.4	26.2	2.5	7.9	119
SEm±	0.3	0.59	1.3	1.2	1.8	33.2	18320	18320	0.09	1.2	0.14	0.37	5.2
CD (p=0.05)	0.9	1.76	NS	NS	5.4	94.6	54058	54057	0.27	3.5	NS	1.1	15.5
Interaction A×B													
SEm±	0.4	0.84	1.8	1.7	2.6	47.0	25909	25908	0.13	1.7	0.2	0.52	7.4
CD (p=0.05)	NS	NS	NS	NS	NS	133.8	NS	NS	NS	NS	NS	NS	NS
Intra row spacing (C)													
10 cm	4.0	9.5	16.4	18.4	48.3	264261	482597	218336	1.8	31.0	2.9	8.5	135
20 cm	4.5	9.2	17.1	18.9	49.7	175372	497871	322499	2.8	27.1	2.67	7.8	123
SEm±	0.26	0.54	0.8	0.8	1.4	19.1	14212	15594	0.1	0.5	0.08	0.17	2.6
CD (p=0.05)	NS	NS	NS	NS	NS	54.6	NS	54057	0.3	1.3	0.24	0.48	7.5
Interaction A×C													
SEm±	0.38	0.78	1.2	1.2	2	27.1	20099	22053	0.15	0.65	0.12	0.23	3.6
CD (p=0.05)	NS	NS	NS	NS	NS	77.2	NS	NS	NS	1.9	NS	NS	NS
Interaction B×C													
SEm±	0.65	1.3	1.9	2	3.5	47.0	34813	38197	0.26	1.1	0.2	0.41	6.3
CD (p=0.05)	NS	NS	NS	NS	NS	133.8	NS	NS	NS	NS	NS	NS	NS
Interaction A×B×C													
SEm±	0.92	1.9	2.8	2.9	4.9	66.5	49233	54020	0.38	1.6	0.29	0.57	8.8
CD (p=0.05)	1.3	NS	NS	NS	NS	189.3	NS	NS	NS	NS	NS	NS	NS

1 US$=INR 72.80 and INR 74.95 (Average value of February, harvesting month)

Highest total tuber yield was recorded with 114 DAP haulm cut (59.1 t ha^{-1}) compared to 39.0 t ha^{-1} with 90 DAP haulm cut. Upadhyay and Bashyal, 2020 reported higher seed and total yield in later dates of haulm cutting (75 and 80 days) than earlier haulm cuttings (65 and 70 days). Planting of 120 g seed tubers recorded highest total tuber yield (55.5 t ha^{-1}) which was significantly higher than 20 g whole tubers (45.6 t ha^{-1}), 20 g cut tubers (42.7 t ha^{-1}) and 40 g cut tubers (42.7 t ha^{-1}). Gulluogl and Arıoglu (2009) also indicated that small seeds gave the lowest tuber yield plant^{-1} due to increasing competition among stem m^2 density, whereas large tubers encountered the least competition and gave the highest tuber yield plant^{-1} at same stem density. Dagne et al., 2018 found that total tuber yield increased when seed tuber sizes increased from small to large as planting materials. The significant difference in tuber yields might be due to large seed tuber size attributed high amount of food reserves that produce highest tuber yields. Ebrahim et al., 2018 also found that among seed tuber sizes, medium to large sizes resulted in higher total tuber yield than the small tuber size (25–34 mm). Pieterse et al. (1986) also reported that appearance, growth, vigour and yield of crops grown from half and quarter seed pieces of potatoes (100, 150 and 200 g) did not differ significantly from that of crops grown from whole seed tubers of the same mass. Cutting as such had no adverse effect on the production capability of a seed tuber. Higher total tuber yield was recorded with 20 cm intra row spacing which was statistically same with 10cm intra row spacing. Dagne et al., 2018 explained that it might be due to efficient use of available soil nutrients and other growth factors in plants grown at closer plant spacing than wider plant spacing. Tubers, under stressed plants may actually bulk sooner and faster than those under healthy, unstressed plants. However, this usually occurs at the expense of canopy development (Akasa et al., 2014). Highest yield at the closest spacing might have been due to the presence of the greatest number of plants. Foliage coverage increased with an increase in the plant density which was found to be related to higher tuber yield. Closer spacing increased the yield of tubers (Sadawarti et al., 2017; Sadawarti et al., 2020).

3.4. *Fresh and dry haulm weight and tuber dry weight*

Significantly higher fresh haulm yield was recorded with 90 DAP haulm cut (36.7 t ha^{-1}) which was significantly higher than 114 DAP haulm cut (20.9 t ha^{-1}). Planting of 120 g seed tubers recorded highest fresh haulm yield (32.0 t ha^{-1}) which was significantly higher than 20 g whole seed (27.8 t ha^{-1}), 20 g cut seed (25.9 t ha^{-1}) and 40 g cut seeds (26.2 t ha^{-1}). Ebrahim et al., 2018 also reported that medium to large seed tuber size resulted in larger shoot fresh weight. Whereas, small seed tuber size (25–34 mm) attributed to only a small fresh weight. Medium seed tuber size (35–45 mm) had a similar impact as the larger seed tuber size (46–55 mm) on production of shoot fresh weight. 20 cm intra row spacing recorded significantly higher fresh haulm yield compared to 10 cm intra row spacing. Interaction of days of haulm cut x intra row spacing was significant and 90 days haulm cut×10 cm intra row spacing recorded highest fresh haulm yield (40.0 t ha^{-1}) however it was lowest (20.5 t ha^{-1}) with 114 days haulm cut×20 cm intra row spacing. Significantly higher dry haulm yield was recorded with 90 DAP haulm cut (3.2 t ha^{-1}) which was significantly higher than 114 DAP haulm cut (2.4 t ha^{-1}). Dry haulm yield was statistically same under different treatments. Significantly higher dry haulm yield was recorded under 10 cm intra-row spacing (2.9 t ha^{-1}) which was significantly higher than 20 cm intra row spacing (2.6 t ha^{-1}). Significantly higher dry tuber yield was recorded with 114 DAP haulm cut (10.2 t ha^{-1}) which was significantly higher than 90 DAP haulm cut (6.3 t ha^{-1}). Mean dry matter increased when dehaulming was delayed from 70 DAP to 80 DAP (Marwaha et al, 2012 Upadhyay and Bashyal, 2020). Positive impact on dry matter content of potato cultivars was reported by Karan (2021). Planting of 80 g seed tubers recorded highest dry tuber yield (9 t ha^{-1}) which was significantly higher than 20 g whole seed (7.6 t ha^{-1}) and 20 g (7.2 t ha^{-1}) cut tubers. Significantly higher dry tuber yield was recorded under 10 cm intra-row spacing (8.5 t ha^{-1}) which was significantly higher than 20 cm intra row spacing (7.8 t ha^{-1}). Foliage coverage increased with an increase in the plant density which was found to be related to higher haulm yield.

3.5. *Water productivity*

Haulm cutting at 114 DAP recorded highest water use efficiency (147kg tuber ha^{-1} mm) compared to 90 days after haulm cutting (111 kg tuber ha^{-1} mm). Planting of 120 g seed tubers recorded highest water use efficiency (146 kg tuber ha^{-1} mm) which was significantly higher than 20 g whole tubers and 20 and 40 g cut tubers. Water use efficiency of 40, 80 and 120 g seed tubers was statistically on par. Significantly higher water use efficiency (135 kg tuber ha^{-1}mm) was recorded with 10 cm intra row spacing which was significantly higher than 20 cm intra row spacing (123 kg tuber ha^{-1} mm). Interaction of days of haulm cut, size of seed tubers/cut tuber and intra row spacings was non-significant. (Singh and Lal, 2013)

3.6. *Economics*

Higher cost of cultivation was recorded with 114 DAP haulm cut (₹ 226577 ha^{-1}) which was significantly higher than 90 DAP haulm cut. Increasing seed sizes increased cost of cultivation. Highest cost of cultivation was recorded with the use of 120 g seed (₹ 386483 ha^{-1}) which was significantly higher than all other seed sizes. Lowest cost of cultivation was recorded with the use of 20 g seed (₹ 136883 ha^{-1}). Intra row spacing of 10 cm recorded highest cost of cultivation ₹ 264261 ha^{-1} which was significantly higher than 20 cm intra row spacing (₹ 175372 ha^{-1}). Singh and Kushwah, 2008 also reported reduction in cost of cultivation due to use of lower seed rate. Highest gross return (₹ 590661 ha^{-1}) was recorded with 114 DAP haulm cut which was significantly higher than 90 DAP haulm cut (₹ 389807 ha^{-1}). Planting with 120 g seed size tubers recorded highest gross return (₹ 555346 ha^{-1}) which was significantly higher than 20 g whole tubers (₹ 456169 ha^{-1}), 20 g cut tubers (₹ 426886 ha^{-1}) and 40 g cut tubers (₹ 454167 ha^{-1}). However gross return under 40 g, 80 g and 120 g planted tubers was statistically same. Gross return under 10 cm and 20 cm planting was statistically same. Highest net return (₹ 364084 ha^{-1}) was recorded with 114 DAP haulm cut which was significantly higher than 90 DAP haulm cut (₹ 176750 ha^{-1}). Planting with 40 g seed size tubers recorded highest net return (₹ 329822 ha^{-1}) which was significantly higher than 80g whole tubers (₹ 246047 ha^{-1}), 120 g whole tubers (₹ 168863 ha^{-1}) and 40 g cut tubers (₹ 267684 ha^{-1}). Intra row spacing of 20 cm recorded higher net income which was significantly higher than 10cm intra row spacing. Highest benefit-cost ratio (2.6) was recorded with 114 DAP haulm cut which was significantly higher than 90 DAP haulm cut (1.8). Planting with 20 g seed size tubers recorded highest benefit-cost ratio (3.3) which was significantly higher than all other seed size/cuts. Intra row spacing of 20 cm recorded significantly higher benefit-cost ratio (2.8) compared to 10cm intra row spacing (1.8). Under West Bengal conditions use of 50×15 cm^2 spacing along with haulm cutting at 65 DAP, when planting is done on first week of November and grown with 50% RDF of NPK was found best (Mandal, 2020).

4. CONCLUSION

40–50 g whole seed size and >50 g tubers as cut seed pieces along with inter row spacing of 20 cm and haulm cutting at 114 day found to be best combination for higher net income in potato cultivation of high bulking variety Kufri Mohan.

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