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SP Singh
Principal Scientist, ICAR-Central Potato Research Station, Maharajpura, Gwalior, Madhya Pradesh, India

SK Sharma
Senior Technical Officer, ICAR-Central Potato Research Station, Maharajpura, Gwalior, Madhya Pradesh, India

MJ Sadawarti
Scientist, ICAR-Central Potato Research Station, Maharajpura, Gwalior, Madhya Pradesh, India

Corresponding Author:
SP Singh
Principal Scientist, ICAR-Central Potato Research Station, Maharajpura, Gwalior, Madhya Pradesh, India

Evaluation of different options for enhancing proportion of seed size tubers in early bulking potato (*Solanum tuberosum* L) variety Kufri Khyati

SP Singh, SK Sharma and MJ Sadawarti

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Abstract
To improve the production of seed size tubers in potato (*Solanum tuberosum*) a field experiment was conducted at Central Potato Research Station Gwalior, MP, during 2013-14 and 2014-15 to study the effect of intra-row spacing, nitrogen levels and date of haulm cutting on production of higher proportion of seed tubers. Highest seed size tuber yield (9.5 t/ha) was recorded with closer intra - row spacing of 15 cm which was significantly higher over 20 cm intra - row spacing. Highest seed size tuber yield (10.1 t/ha) was recorded with the treatment having 15 cm intra - row spacing x 120 kg N x 80 days haulm cut. Higher dose of nitrogen application increased N (136 kg/ha) and P (6.3 kg/ha) uptake however closer intra - row spacing increased K uptake (105 kg/ha). Highest N content (176 kg/ha) of soil was recorded with 20 cm intra - row spacing x 120 kg N and 70 days haulm cut. OC content (0.33%) was highest with 80 days haulm cut. Significantly higher severe mosaic incidence (1.49%) was observed with closure intra row spacing of 15 cm. Significantly higher severe (1.49%) and mild mosaic (1.71%) incidence were observed with 80 days haulm cut over 70 days. However, in contrast highest net return (251 thousand/ha) was recorded with 20 cm intra - row spacing x 80 days haulm cut x 120 kg N/ha. Similarly in contrast, highest B:C ratio 3.0 was observed with 20 cm intra - row spacing 80 days haulm cut x 120 kg N/ha.

Keywords: Seed size tubers, haulm cut, intra-row spacing, nutrient uptake, mosaic, net return, B:C ratio

Introduction
Potatoes are unique from many crops in that they rely heavily on vegetative (asexual) propagation for production rather than botanical seed. Tubers are used as the primary reproductive unit and are referred as “Seed potatoes”. Due to input intensive nature of the crop, adoption of optimum cultural practices for achieving higher potato productivity becomes a limiting factor for small and marginal farmers. Seed is the costliest input in potato production and accounts for about 40% of the cost of production (Kushwah and Singh, 2011) [9]. Seed rate depends on the size of tubers used in planting for ware as well as seed crop. In general, 25-50g tubers are recommended for ware as well as seed production in plains (Kushwah and Singh, 2010) [18]. Potato tubers are planted either as whole unit (single- drop seed) or as cut seed. Cutting seed potatoes typically provides an economic advantage to growers, especially when tubers are too large to fit into a planter or to reduce seed cost. Though cut seed pieces reduce on seed cost but liable to get infected with viral diseases. Hence, demand for small seed tubers is high in seed market (Kushwah and Singh, 2008) [17].
Seed size influences the seed rate per hectare (Kushwah and Singh, 2010; Kumar *et al*., 2009) [18, 7]. The number of sprouts that develop from a seed tuber is influenced by the size of seed. Larger tubers generally produce more sprouts, but if larger seed is used, a greater weight of seed must be planted per unit area (Kushwah and Singh, 2010) [18]. Conversely, smaller tubers have more sprouts per unit weight than larger tubers, hence most farmers prefer to plant small tubers. Young seed is more vigorous, later maturing and therefore higher yielding. The goal of most commercial producers is to maximize profits and maintain or expand the farms productivity long term. Commercial producers often manipulate in field production such as the yield of the most valuable tuber sizes is maximized (Kushwah and Singh, 2010) [18]. The tuber size profile can be reduced or expanded by altering inter and intra row seed spacing,

controlling days of growth by planting late or killing vines/haulm early, regulating inputs like fertilizer and water, applying growth regulators, and manipulating seed tuber physiological age.

Potato tubers are either planted as whole units (single-drop seed) or as cut seed, whereby tubers are cut into seed pieces that typically contain two or three eyes. Cutting seed potatoes typically provides an economic advantage to potato growers, especially when tubers are too large by reducing on seed cost but cutting of tubers is liable to spread viral diseases (Kushwah and Singh, 2011) [9] hence disease free seed size whole tubers always remain in demand.

Materials and methods

A field experiment was conducted on fixed plots for two consecutive years in split plot design with cultivar Kufri Khyati at Central Potato Research Station (26^0N and 78^0E, 207 m above sea level and receives annual rainfall 400-800 mm), Gwalior, MP, during 2013-14 and 2014-15. Rainfall is the main source of replenishment at the farm. Atmospheric temperature varies from 7.1 to 43^0 C. Mean soil temperature varies from 14 to 33^0C. However, during experimentation mean temperature ranged from 7.8 to 33.8. Wind velocity varies from 2.3 to 4.7 km/hr during crop season. The soil of the experimental field was silty clay loam having organic carbon 0.39%, available N 125, P 41 and K 330 kg/ha, pH 7.0 and EC 0.2 dS/m, Cu 0.9 ppm, Zn 0.94 ppm, Fe 17 ppm and Mg 0.88 ppm. Organic carbon content of soils is generally low because of high temperature in summers. Soil is heavy textured having high silt and clay contents. Treatments consisted of two intra-row seed spacing (S1-15 cm, S2-20 cm) as main plot and two dates of haulm cutting (70 - Days after planting, 80 Days after planting) as sub plot and two nitrogen levels (N1-120 and N2-150 kg/ha) as sub - sub plots. Treatments were replicated three times. Well sprouted seed tubers of cv. Kufri Khyati were planted on 2.11.2013 and 4.11.2014 during first and second years, respectively. Spacing for planting was kept at 60 cm as inter - row spacing. Fertilizer P and K were applied @ 26 and 84 kg/ha, respectively. Full doses of P and K and half dose of N were applied at the time of planting and remaining half dose of N was applied through urea at the time of earthing up which was done 25 days after planting (DAP). At planting, half dose of nitrogen with full dose of phosphorus and potassium were applied through ammonium sulphate, single super phosphate and muriate of potash, respectively. Haulm killing was done on 12.1.2014, 22.1.2014 and 14.1.2015, 24.1.2015 during first and second years, respectively. Overall, 4 irrigations were applied in 2014 and 5 irrigations in 2015 accounting winter rains. Plants infected with viruses (severe and mild mosaics) were got recorded. Haulm cutting was done at respective dates after 70 and 80 days after planting as per treatment. To control late blight, Dithane M45 was sprayed @ 0.2% at 60 days stage of crop growth. Imidacloprid and trizophos were sprayed alternatively at 10 days interval starting from emergence of crop until 10 days before haulm cutting. Tubers were harvested 20 days after haulm cutting on hardening of tuber skin. Cost of cultivation was worked out using common cost of cultivation and adding seed cost and nitrogen cost as variable one. Observations on crop growth and yield attributes were recorded at 60 DAP and at harvest of the crop. Soil sampling was done before start of the experiment from all the three replications and from each plot on completion of experiment. Chemical analysis was done following standard procedure of analysis for N, P, K, pH, EC.

Results and discussion

Growth Attributes: Closer intra row planting of tubers resulted into increased plant height though it was statistically at par with normal planting. There was no any significant effect of intra row spacing on growth attributes viz. plant height, leaves/plant and stem/plant. Knowles and Knowles (2006) [5] reported that stem number/plant affect tuber size profile. Similarly there was no any significant effect of days of haulm cut on either of the growth attributes. Results are in conformity with Singh and Bhatnagar (2014) [14]. Interaction of spacing, days of haulm cutting and nitrogen levels was found significant & highest plant height was recorded with 15 cm intra row spacing, 150 kg N/ha and 70 days of haulm cutting. Number of leaves/plant were highest with 20 cm spacing x 120 kg N and 80 days of haulm cut. Firman and Allen, 1989 rapid establishment of leaf area for early capture of solar radiation is essential for optimizing final tuber yield and dry matter content. Number of stem/plant was highest with 15 cm spacing x 150 kg N x 80 days of haulm cut. Number of stem/plant was highest with 15cm. spacing x 150 kg N x 80 days of haulm cutting.

Yield attributes: There was no any significant effect of intra – row spacing on under size, seed size, over size or total tuber number. Increasing days of haulm cutting from 70 to 80 days did not exert any significant effect on increased number of under size, seed size and total number of tubers. However, increasing days of haulm cut significantly increased over size tubers. Interaction of spacing x nitrogen x days to haulm cut was significant. Highest number of under size tubers was recorded with 15 cm intra – row spacing x 120 Kg N/ha x 70 days of haulm cutting. Highest number of seed size tubers was recorded with 20 cm spacing x 120 Kg N/ha x 80 days of haulm cut. Similar results were also reported by (Pavek and Thornton, 2006) [10]. Final tuber number/plant is influenced by temperature, soil moisture, plant health and disease, planting depth and cultivar, plant spacing, seed tuber physiological age (Knowles and Knowles, 2006) [5], soil fertility and irradiance.

Viral Disease Status: Intra- row spacing did not show any significant effect on off type and severe mosaic incidence. Significantly higher disease incidence was observed with closure intra row spacing of 15 cm. Significantly higher severe and mild mosaic incidence were observed with 80 days haulm cut over 70 days haulm cut. Interaction of spacing x N levels and days to haulm cut were not found significant. Singh and Kushwah (2008) [9] also reported similar results.

Yield of tubers: There was no any significant effect of intra – row spacing on yield of under size, over size and total tuber yield. Highest seed size tuber yield was recorded with closer intra row spacing of 15 cm which was significantly higher over 20 cm intra – row spacing. Dua *et al*. 2008 [2] also reported that 15 cm intra - row spacing increased proportion of seed tubers over 10 cm intra – row 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. There was no any significant effect of days of haulm cut on production of under size and seed size tubers. Kumar *et al.*, 2009 [7] also reported similar results. Significantly higher seed size tubers were recorded with 80 days haulm cut over 70 days haulm cut. Kumar *et al*. 2009 [7] also reported highest seed size and total tuber yield was obtained with the treatment combination of 30-40 g seed tuber size and haulm killing at 90 DAP.

Significantly higher total tuber yield was recorded with 80 days haulm cut which was significantly higher over 70 days haulm cut. Inter action of intra – row spacing x nitrogen x days to haulm cut was significant. Highest yield of under size tubers was recorded with 15 cm x 120 kgN x 70 days haulm cut. Highest seed size tuber yield was recorded with 15cm x 120kg N x 80 days haulm cut. Bishop and Wright (1959) [1] reported that potato size was determined more by spacing than by seed piece size. Too much nitrogen early in the season may promote excessive foliar growth and delay tuberization, limiting the available window for bulking and resulting in reduced yield over the available growing season (Knowles *et al*, 2013) [6]. It is well known that lower dose of nitrogen will generally set tubers early and produce less foliar growth and result in early foliar senescence, tuber maturity. Interaction was found non- significant as far as over size tuber yield was concerned. Highest total tuber yield was recorded with 20 cm x 120 kg N x 80 day haulm cut. Plants growing in favorable environments free of pests and diseases with sufficient water, nutrient, and heat units are likely to produce a larger canopy and greater tuber yields than those grown under stress. Knowles *et al*., 2013 [6] also reported similar results.

Nutrient uptake: There was no any significant effect of intra row spacing on nutrients N, P, K uptake. Significantly higher N, P, K uptake was recorded with 80 days haulm cut over 70 days haulm cut. Singh *et al*., 2012 also reported that longer the duration results into higher uptake of nutrients. Application of 150 Kg N/ha, significantly increased N and P uptakes over 120 Kg N/ha. Singh and Bhatnagar, 2013 [13] also reported similar results. Interaction of spacing x N levels x days of haulm cut was statistically at par with regard to N uptake though it was highest with 15 cm x 150 Kg N/ha x 70 days haulm cut. Results are in conformity with Singh *et al*., 2007 [12] and Singh and Dua, 2015 [16]. Interaction was significant with regards to P uptake. Highest P uptake was recorded with 20 cm x 120 Kg N/ha x 80 days haul cut. However K uptake was highest with 15 cm intra row spacing x 150 Kg N/ha x 80 days haulm cut. Results are in conformity with Khurana and Bhutani, 2003 [4] and Kushwah and Singh, 2008 [8].

Nutrient status of soil: There was no any significant effect of intra row spacing on pH of soil. Electrical conductivity was significantly higher with 15 cm intra row spacing over normal intra row spacing. Organic carbon was significantly higher with 15 cm intra row spacing over 20 cm. Nitrogen content of soil was significantly higher with 15 cm intra row spacing over 20 cm intra row spacing. Days of haulm cut did not showed any significant effect on nitrogen content of soil. There was no any significant effect of nitrogen application on nitrogen content of soil. Interaction effect was found to be significant. Highest N content of soil was recorded with 20 cm spacing x 120 kg N and 70 days haulm cut. There was no any significant effect of intra row spacing on P content of soil significantly higher K content was recorded in 15 cm intra – row spacing over normal spacing (20 cm). Significantly higher pH and EC was recorded with 80 days haulm cut however OC (%) was highest with 70 days haulm cut. Significantly higher P and K contents were recorded with 80 days haulm cut over 70 days haulm cut. Significantly higher pH, EC and OC were recorded with 150 kg N/ha over 120 Kg. Similarly P and K contents were also significantly higher with 150 kg/ha over 120 kg. Interaction of spacing x N levels x days to haulm cut were significant. Highest pH and EC were recorded with 15 cm intra – row x 150 Kg N x 80 days haulm cut. Organic content was highest with intra – row spacing (20 cm) x 120 kg N x 70 day haulm cut. Highest P content of soil was recorded with 20 cm intra – row x 120 kg N x 70 day haulm cut. Highest K content was recorded with 15 cm intra – row x 150 kg N x 70 day haulm cut.

Economics: Highest cost of cultivation (Rs 144 thousand/ha) was recorded with closer intra-row spacing over 20 cm intra-row spacing. Cost of cultivation increased by Rs 17 thousand/ha due to reduction in intra – row spacing by 5cm. Singh and Kushwah, 2008 [8] also reported reduction in cost of cultivation due to use of lower seed rate. Application of higher dose of nitrogen increased cost of cultivation by Rs1000/ha. Highest gross return (Rs 361 thousand/ha) was recorded with closure intra-row spacing of 15cm. Higher gross return was recorded with 80 days haulm cut compared to 70 days. Increase in gross return was on account of increase in tuber yield (Kushwah and Singh, 2011) [9]. Highest gross return was recorded with 20cm intra row spacing x 120 kg N x 80 day haulm cut.It might be due to synergistic interaction among the three factors. However, in contrast highest net return was recorded with 20 cm intra row spacing. 80 days haulm cut and 120 kg N/ha. Similarly in contrast, highest B:C ratio was observed with 20 cm intra row spacing, 80 days haulm cut and 120 kg N/ha. Increased cost on seed and fertilizer inputs was not in accordance with increase in tuber yield (Kushwah and Singh, 2011; Bishop and Wright, 1959) [9, 1].

Based on above study, option of lower dose of nitrogen (120 kg N/ha) x 20 cm intra – row spacing and 70 days of haulm cutting is good for getting higher proportion of healthy seed size tubers.

Table 1: Effect of different treatments on growth and yield attributes (two years mean data)

Treatments	Plant height (cm)	leaves/plant	stem/plant	Number of tubers ('000/ha)			
				Under size (<25g)	Seed size (25-75g)	Over size (>75g)	Total
Spacing							
S-1(15 cm)	52	62	2.8	144	136	130	411
S-2 (20 cm)	48	62	2.1	115	129	136	381
SEm ±	2	6	0.2	14	7	5	25
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS
DOH (days of haulm cut)							
(D-1)70 days	57	60	2.3	128	128	127	370
D-2 (80 days)	56	64	2.5	132	137	143	412
SEm ±	3	5	0.5	13	7	9	18
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS
N level (kg/ha)							
N-1 (120)	35	27	1.3	78	69	65	212

N2-(150)	52	62	2.4	124	128	134	386
SEm +	3	6	0.3	12	10	10	23
CD(P=0.05)	11	13	0.6	28	23	24	53
Interactions							
S1N1D1	57	56	2.7	157	130	125	413
S1N1D2	52	54	2.5	153	148	133	434
S1N2D1	66	71	2.7	137	148	127	412
S1N2D2	60	67	3.1	130	119	135	385
S2N1D1	49	64	2.1	101	118	126	345
S2N1D2	60	73	2.7	130	154	145	430
S2N2D1	55	50	1.7	116	117	117	350
S2N2D2	51	61	1.9	113	129	157	399
SEm +	6	11	0.5	24	20	21	46
CD(P=0.05)	14	26	1.2	55	46	48	106

Table 2: Effect of different treatments on tuber yield and nutrient uptake (two years mean data)

Treatments	Yield of tubers t/ha				Nutrient uptake (kg/ha)		
	Under size (<25g)	Seed size (25-75g)	Over size (>75g)	Total	N	P	K
Spacing							
S-1(15 cm)	2.1	9.5	28.2	39.8	141	7.3	105
S-2 (20 cm)	1.6	8.3	29.1	38.9	131	7.0	99
SEm +	0.2	0.2	2.4	2.5	7	0.4	6
CD(P=0.05)	NS	0.9	NS	NS	NS	NS	NS
DOH (days of haulm cut)							
(D-1)70 days	1.7	8.7	26.7	37.3	130	6.7	96
D-2 (80 days)	1.9	9.0	30.6	41.5	143	7.6	108
SEm +	0.1	0.6	1.2	1.3	4	0.3	3
CD(P=0.05)	NS	NS	3.3	3.6	11	0.8	9
N level (kg/ha)							
N-1 (120)	1.1	4.9	14.1	20.1	70	4.1	102
N2-(150)	1.8	8.5	28.3	38.6	136	6.3	102
SEm +	0.1	0.4	1.6	1.6	7	0.3	5
CD(P=0.05)	0.3	0.9	3.7	3.7	16	0.7	NS
Interactions							
S1N1D1	2.2	9.5	27.4	39.1	135	8.1	103
S1N1D2	2.1	10.1	29.1	41.3	144	8.2	106
S1N2D1	2.1	9.7	25.4	37.1	138	6.0	99
S1N2D2	2.2	8.5	31.0	41.8	148	6.9	112
S2N1D1	1.5	8.1	28.6	38.2	126	7.1	92
S2N1D2	1.9	9.3	30.8	42.0	142	8.7	109
S2N2D1	1.4	7.5	25.5	34.5	119	5.6	90
S2N2D2	1.5	8.1	31.4	41.1	138	6.6	106
SEm +	0.2	0.8	3.2	3.2	14	0.6	9
CD(P=0.05)	0.6	1.8	NS	7.5	NS	1.3	21

Table 3: Effect of different treatments on nutrient status and economics of potato seed production (two years mean data)

Treatments	Nutrient status of soil (Kg/ha)						Economics			
	pH	EC (dS/m)	OC (%)	N	P	K	Cultivation cost (₹ '000/ha)	Gross return (₹ '000/ha)	Net return (₹ '000/ha)	B:C ratio
Spacing										
S-1(15 cm)	6.4	0.40	0.35	162	73	327	144	361	217	2.5
S-2 (20 cm)	6.4	0.34	0.32	158	76	296	127	348	221	2.7
SEm +	0.0	0.00	0.01	0.7	2	3	0	21	21	0.2
CD (P=0.05)	NS	0.01	0.02	3.1	NS	14	0	89	89	0.7
DOH (days of haulm cut)										
(D-1)70 days	6.3	0.34	0.16	160	78	162	135	337	201	2.5
D-2 (80 days)	6.5	0.37	0.33	159	72	308	135	372	237	2.8
SEm +	0.0	0.06	0.02	2.7	1	10	0	11	11	0.1
CD (P=0.05)	0.0	NS	0.05	NS	2	27	0	32	32	0.2
N level (kg/ha)										
N-1 (120)	3.2	0.19	0.18	162	36	158	135	362	227	2.7
N2-(150)	6.5	0.36	0.31	157	71	311	136	346	211	2.6
SEm +	0.1	0.03	0.03	5	3	15	0	13	13	0.1
CD (P=0.05)	0.2	0.06	0.08	11	7	34	0	31	31	0.2
Interactions										
S1N1D1	6.4	0.41	0.32	158	72	286	144	356	212	2.5
S1N1D2	6.3	0.36	0.41	171	73	348	144	375	232	2.6
S1N2D1	6.4	0.40	0.30	155	84	362	144	340	196	2.4
S1N2D2	6.6	0.43	0.36	164	64	315	144	373	229	2.6

S2N1D1	6.2	0.41	0.44	176	88	319	127	342	215	2.7
S2N1D2	6.5	0.34	0.23	145	81	298	127	377	250	3.0
S2N2D1	6.4	0.26	0.28	152	68	295	127	309	182	2.4
S2N2D2	6.6	0.37	0.32	158	68	273	127	364	237	2.9
SEm ±	0.1	0.05	0.07	10	6	29	0	27	27	0.2
CD (P=0.05)	0.3	0.12	0.16	23	14	68	0	62	62	0.5

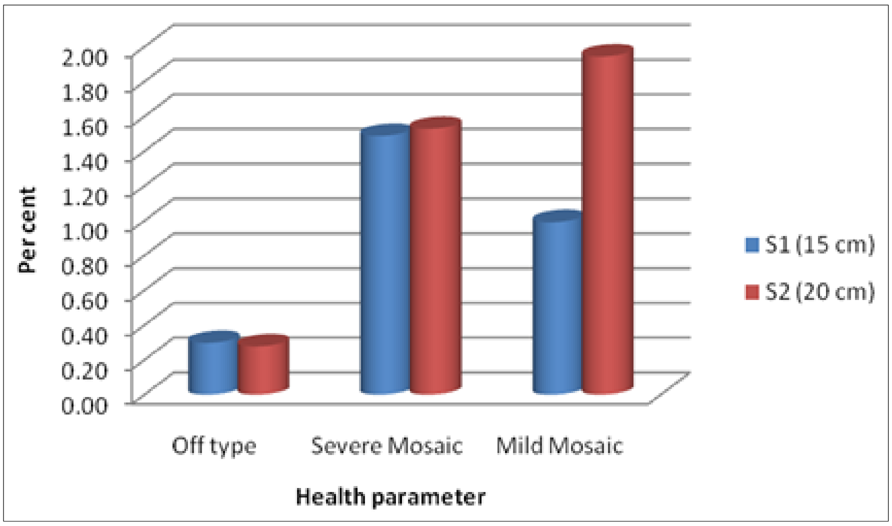

Fig 1: Effect of intra – row spacing on mosaic incidence (%)

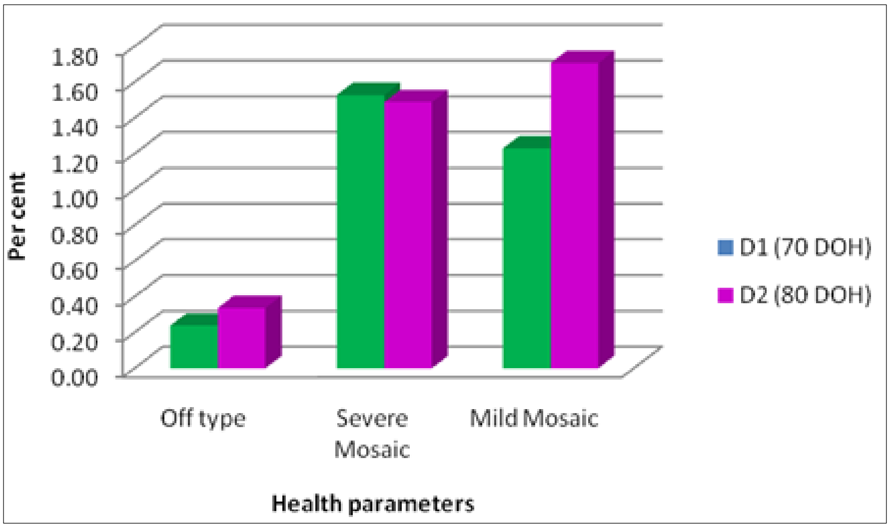

Fig 2: Effect of intra – row spacing on mosaic incidence (%)

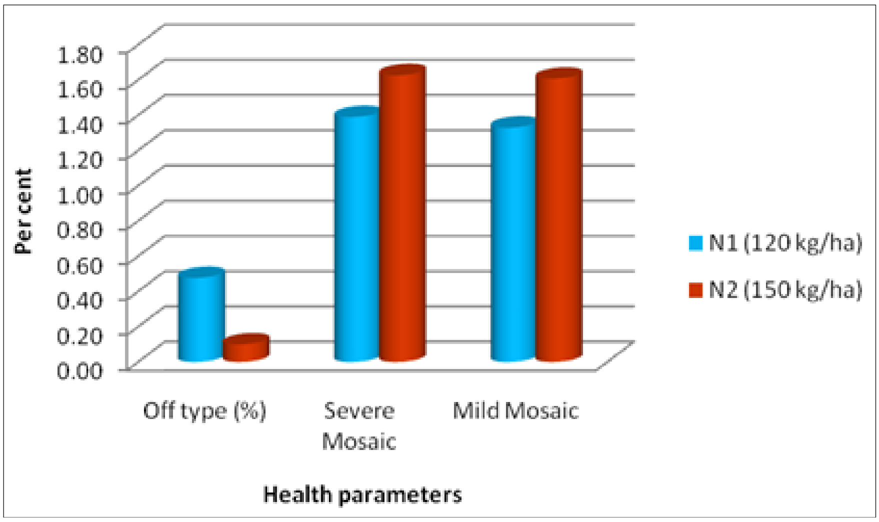

Fig 3: Effect of intra – row spacing on mosaic incidence (%)

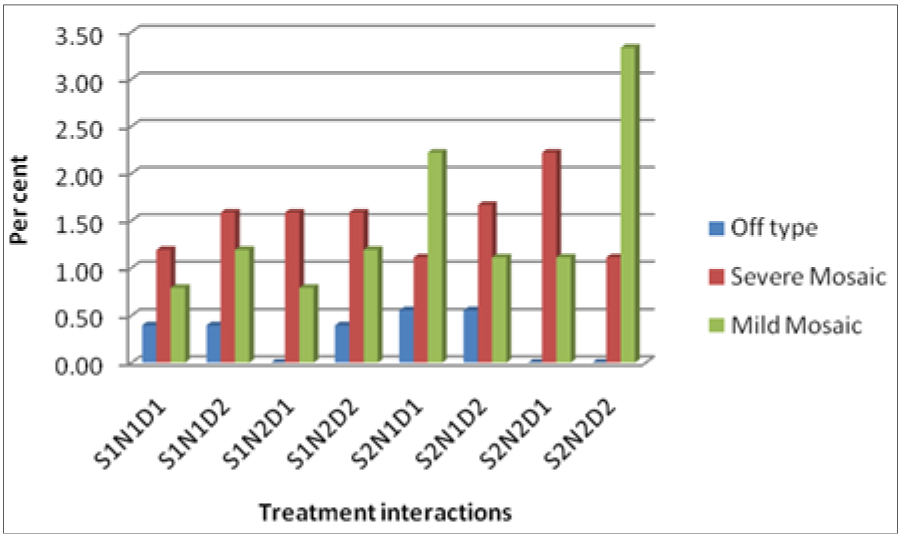

Fig 4: Effect of intra – row spacing on mosaic incidence (%)

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