Studies on Machine-Crop Parameters for Chickpea Seed Crop Threshing

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ABSTRACT

Seed crop of legumes are very critical to mechanical abuses. Even minor injury to seed reduces major seed quality considerably. The protruding structure of chickpea makes it more critical. Also, timeliness is important factor in seed production system in light of weather vagaries. Further, conventional threshing operations always coupled with reduced recovery, labor consuming and uneconomical. The present study was conducted in view to optimize important operational and crop parameters influencing the threshing of chickpea seed crop. Moisture content, concave clearance and cylinder speed were taken as independent parameters and visible injury, internal injury, germination percentage and threshing efficiency were studied as dependent parameters. Cylinder speed was found the most critical factor for affecting visible and internal injury extent. Moisture content adversely affected the internal injury levels in threshed seed. Cylinder speed: 8.94 m/s, concave clearance: 14 mm and moisture content: 10 per cent were resulted seed of optimum quality with minimal visible and internal injury coupled with optimum threshing efficiency.

Keyword: Cylinder rotation speed, internal injury, electrical conductivity, threshing, chickpea.

1. INTRODUCTION

The pulse production has remained relatively stagnant but also the crop area has declined substantially in Indian subcontinent. Stagnant production and growing demand have led to rising pulse prices and declining per capita consumptions in India (31.5 g/day) as against the minimum requirement of 70 g/day (Rahman *et al*, 2005). Chickpea is the most important pulse crop of India. However, its productivity is very low. One of the important reasons for low productivity is non-avialability of quality seed. Among all the major crops of the country, avialability of quality seed of chickpea is least i.e. about 2 % (NSP, 2005). Furthermore, multi-location coordinated trials under National Seed Project (crops) demonstrated that about 20-30 per cent average increase in productivity could be achieved with the use of quality seed (Chowdhary, 2004).

Chickpea seed being dicotyledonous and the germ tip being located at the protruding structure, makes it prone to mechanical injuries. Traditionally, chickpea is threshed by manual beating of plants with stick or trampling under the hooves of animals or under tractor wheels which is not only labour intensive, tedious and time consuming but also causes damage in form of bruising of seed coat or splitting, resulting in low recovery. Commercially available mechanical threshers are mainly for paddy, wheat, etc. thresher for podded crops, like chickpea, cowpea, field pea and soybean etc. has not yet been commercialized. Hence, researchers and farmers made attempts to use commercially available paddy threshers with wire loop cylinder (Devnani, 1976), wheat threshers with raspbar or peg tooth cylinder

(Kulkarni and Singh, 1986) and axial flow thresher with peg tooth cylinder as dual or multicrop thresher to thresh chickpea and other pulse grain crop (Majumdar, 1985). But significant amount of visible damages were observed. However, reduction in visible damage was observed with changing the operational parameters of threshing. The common cause of damage in grain/seed mechanical handling is the particle velocity and rigidity (Paulsen, 1978 and Paulsen *et al*, 1981). In light of above facts, the present study was undertaken to study and optimize important operational and crop parameters influencing the threshing of chickpea seed crop threshing.

2. MATERIALS AND METHODS

2.1 Plot Thresher

The commercially available pot thresher (Fig. 1) was taken for the study. It consisted of peg-tooth type cylinder, concave, separating and cleaning unit. Electric motor of 5 kw, 3 phase was used as power source. Power from motor was transmitted to threshing drum, separation unit and air cleaning system by set of V-belt and pulley arrangement. The crop was fed to thresher from feeding chute placed on top. Threshing accomplishes by rotating cylinder and open type concave. The cylinder consisted of total 70 pegs, placed at 70 mm apart in staggered arrangement among ten rows. Five rows of pegs were mounted on concave in staggered fashion. Each row carried six peg placed 70 mm apart in such a way that any peg either of cylinder or concave did not strike, when cylinder was rotated. The peg height was adjustable. The threshed product from the cylinder-concave unit follow a specified path by gravitational force coupled with fabricated guides and fall on the oscillating tray. Centrifugal blower produced an air stream, which separate out light plant debris before falling material on oscillating tray. Series of iron wires were place outer end of the tray, which functioned as sieve. Coarse plant part coming with seed scalped off and seed fell down through the space of iron wire and collected at the bottom of thresher.

Fig. 1. A view of plot thresher at experimental site.

2.2 Crop

Seed crop of two varieties of chickpea viz., BG-1088 (*Kabuli)* and BG-1103 (*Desi)* grown with the standard agronomic practices at IARI Regional Station, Karnal during rabi 2005-06 and 2006-07 were taken for the study. After attaining optimum maturity, the crop was harvested manually, in the month of April-May. Both the varieties were of different classes of chickpea commonly known as *Kabuli* and *Desi*. *Kabuli* type chickpea is white in colour while *Desi* type is brown in colour.

2.3 Evaluation procedure

The performance tests of the chickpea threshing were conducted at different three levels of moisture contents, three levels of cylinder speed and three levels of concave clearance by using randomized block design (RBD) of a 3x3x3 factorial experiment with four replications in each treatment and comparison between treatment means by least significance difference (LSD) at 5% level for two varieties separately. The cylinder speeds: 8.05, 8.94 and 13.42 m/s were considered for the experiment and was attained with help of set of driver and driven pulley of different sizes (102, 152, 356 and 406 mm). Three levels of cylinder and concave clearance: 12, 14 and 16 mm were taken. The particular clearance was set by adjusting spike length. Moisture content: 8, 10 and 12 % of seed was taken for the study. The specific moisture content was achieved by shade drying of harvested crop on concrete floor and close monitoring seed moisture content. The moisture content monitoring was accomplished with help of resistance type digital moisture meter. Three levels of moisture content (8, 10 and 12 per cent), three levels of cylinder peripheral speed (8.05, 8.94 and 13.42 m/s), three levels of concave clearance (12, 14 and 16 mm) and two cultivars namely BG – 1088, BG -1103 were taken as independent variables for the experiment. The effect of these independent variables on visual breakage, germination, electrical conductivity (internal damage/injury) and threshing efficiency was considered for the experiment.

The experiments were conducted for thirty minute continuous operation of thresher for particular level of cylinder speed, concave cylinder clearance and moisture content in four replications. Random samples were collected from product port as well as blower output port. These samples were subjected for performance indicators: visible breakage, germination test and electrical conductivity test, analysis.

The visible cracked/injured or splitted seeds were separated from the sample and weighed. The visible breakage percentage was calculated by weight basis of sample and separated injured part weight.

Germination test was conducted according to ISTA rules (1999). Four replicates of 100 seeds were placed between two layers of pre-wet germination papers in germinator set at 20^{o}C, temperature and 85 per cent humidity for 8 days. After eight days, number of normal seedlings, hard seed and abnormal seedlings were recorded. Seedlings were counted as normal, which had well developed root system including a primary root, intact plumule with well developed green leaf. Seeds that did not absorb water was classified as hard seeds. Seedlings which had no primary root system or weak or unbalanced development of the essential structures such as spirally twisted or stunted plumules, swollen shoots or stunted roots or decay or diseased of any essential structures were recorded under abnormal seedling count. The germination per cent was expressed on the basis of normal seedlings (Agarwal, 1985).

Electrical conductivity of seed leachate is measured for seed coat intactness or minor injury to seed. Twenty gram of seeds were soaked in 75 ml of deionized water in 100 ml Erlenmeyer flasks covered with aluminum foil and kept at 20 ^{o}C for 24 h. After 24 h, the contents of each flask were gently stirred and the liquid was separated from the seeds by pouring into a 250 ml beaker (Abdul-Baki and Anderson, 1973). The conductivity of the liquid was measured with digital conductivity meter.

3. RESULTS AND DISCUSSION

3.1 Visible Breakage

The cylinder speed was most prominent in developing damage in seed followed by concave clearance and moisture content. The injury level reached up to 50 per cent for *Kabuli* type seed with 13.42 m/s cylinder speed (Table 1). Reducing the cylinder speed from 13.42 m/s to 8.05 m/s reduced the visible breakage from 50 to 4 per cent in case of *Kabuli* type. However, the damage was observed in the range of 3 to 18 per cent for *Desi* type seed for cylinder speed 13.42 m/s to 8.05 m/s. The concave clearance exhibited negative relation to visible damage across chickpea types. Increase of concave clearance from 12 mm to 16 mm reduced the breakage about half (26.75 to 13.46 and 13.15 to 5.19 % for *Kabuli* and *Desi*, respectively). Moisture content of seed demonstrated positive relation with visible breakage. Substantial reduction in visible breakage was observed with lower level of moisture content. Higher rupture strength of seed at lower moisture levels might be cause of reduced breakage at lower moisture content. Among the first order interactions; cylinder speed, concave clearance and moisture content, were significant for visible breakage. However, interaction of all the parameters was significant only for *Kabuli* type chickpea. Minimal breakage was observed at lowest cylinder speed (8.05 m/s) and highest concave clearance (16 mm) for *Kabuli* and *Desi* type seed threshing. Pronounced interaction effect of moisture content and cylinder speed on breakage was observed at higher moisture level (12 %) and higher cylinder speed: 13.42 m/s, across the chickpea types. Whereas, it was least at cylinder speed; 8.05 m/s and 8 % moisture content. Extent of damage was in the range of 5 to 25 per cent and 4 to 14 per cent for *Kabuli* and *Desi* type chickpea, respectively. Higher concave clearance and lower level of moisture substantially reduced the damage. It is evident that *Kabuli* type seeds are more prone to mechanical damage by cylinder speed, concave clearance and moisture content than *Desi* type seed.

Internal Injury

Electrical conductivity of seed leachate is a measure of minor injury or invisible injury to seed. The cylinder speed affected maximum on electrical conductivity (EC) of leachate followed by concave clearance and moisture content (Table 1). Abrupt rise of electrical conductivity was found at cylinder speed 13.42 m/s. Electrical conductivity exhibited negative correlation with moisture content, across chickpea types. It signified that hard dicotyledonous seed (at low level of moisture content) develop fissures due to lack of restitution. The higher moisture content of seed increased elasticity and in turn, reduced the internal injury were observed. First order of interactions of cylinder speed, concave clearance and moisture content were found significant except interaction of concave clearance and moisture content across the chickpea types (Table 2). At higher cylinder speed and lower level of concave clearance doubled the value of EC. Also, interaction effect of cylinder speed and moisture content on electrical conductivity of seed leachate was more noticeable at higher cylinder speed and lower level of moisture content, across the chickpea type. The more impact at high level of cylinder speed while at lower level of moisture content seed loss of elasticity causative of increased EC value.

Germination

The cylinder speed, concave clearance and moisture content had significant effect on seed germination capacity. Cylinder speed was proven most important factor in affecting germinability followed by concave clearance and moisture content. Germination capacity of seed was reduced drastically from 66.31 to 33.94 per cent and 67.94 to 42.39 per cent in case of *Kabuli* and *Desi* type seed threshing, while the cylinder speed increased from 8.05 m/s to 13.42 m/s (Table 1). However, an increase in germination capacity was observed from 48.47 to 59.41 per cent and 51.83 to 65.33 per cent with increased concave clearance from 12 mm to 16 mm for *Kabuli* type and *Desi* type seed, respectively. Cylinder speed 8.05 m/s and 8.94 m/s was at par with respect to germination percentage for *Desi*. Germinability increased initially but decreased later with increasing moisture content. Moisture content of seed at the time of threshing was observed very critical in affecting germination capacity. Maximum germination was observed at 10 per cent moisture content. The sensitivity of germination percentage to moisture content with mechanical threshing of chickpea might be due to fragile characteristics at lower and higher moisture levels and prone to mechanical abuse. Interactions of cylinder speed, concave clearance and moisture content were found highly significant with respect to germinability of seed across the chickpea types.

Interaction effect of cylinder speed and concave clearance on germination capacity were maximum 75 and 76 per cent for *Kabuli* and *Desi* type at cylinder speed 8.05 m/s and 16 mm concave clearance, respectively across chickpea types (Table 2). Germination percentage of seed was significantly affected by the moisture content and cylinder rotation speed and was observed in the range of 33 - 72 and 39 - 74 per cent for *Kabuli* and *Desi* type seeds. The considerable reduction in germinability of noticed at both lower and higher level of moisture content. The effect of Concave clearance and moisture content on germination percentage was diverged in the range of 46 to 63 per cent and 49 to 70 per cent for *Kabuli* and *Desi* type seed, respectively. The highest value of germination capacity was observed 63 and 70 per cent for *Kabuli* and *Desi* type at 10 per cent moisture content and 16 mm concave clearance, respectively. It suggested that threshing of chickpea seed should be done at close vicinity of 10 per cent moisture content. The sensitivity of moisture content to germination percentage with mechanical threshing of chickpea might be due to fragile characteristics at lower and higher moisture levels.

Threshing Efficiency

Threshing efficiency was directly proportional to cylinder speed; however it was negatively correlated with concave clearance and moisture content. The threshing efficiency increased from 82.67 per cent to 95.08 per cent as cylinder speed increased from 8.05 m/s to 13.42 m/s (Table 1). Higher threshing efficiency at higher cylinder speed was probably due to increased impact force. Minimal threshing efficiency was demonstrated with higher concave clearance, may be due to lack of required force exerted on pod and hence pod escaped without detachment of seed. Interestingly higher threshing efficiency was observed at 10 per cent moisture content than that of 8 and 12 per cent. At lower moisture content plant material became hard and also at higher moisture content it became slightly elastic, which might be reflected as reduction of threshing efficiency. Overall, higher threshing efficiency was observed for *Kabuli* than *Desi*. It might be due to lesser physical strength of *Kabuli* plant parts. The interactions of cylinder speed, concave clearance and moisture content for threshing efficiency were significant at 5 % level of significance.

Interaction effect of concave clearance and cylinder rotation speed was found in the range of 81 to 97 and to 80 to 96 per cent for *Kabuli* and *Desi* type, respectively (Table 2). At higher cylinder speed (13.42 m/s) irrespective of concave clearance level and type of chickpea threshing efficiency was found at par. Also at 12 and 14 mm concave clearances and all the levels of cylinder speed, threshing efficiency was found at par. Moisture content and cylinder speed interaction effect was observed in the range of 76 to 99 and 74 to 97 for *Kabuli* and *Desi* type seed threshing, respectively. As the cylinder speed increased the threshing efficiency increased significantly irrespective to type of chickpea and level of moisture content. It further strengthen that cylinder rotation speed is utmost important factor affecting the threshing operation. Maximum threshing efficiency was observed at 10 per cent moisture content across cylinder rotation speeds and chickpea types. The interaction effect of concave clearance and moisture content on threshing efficiency was observed maximum at 12 mm concave clearance and 10 per cent moisture content for both chickpea types. It might be due to more exertion of impact at lower concave clearance than higher level of concave clearance. And at lower level of moisture content the plant parts became very hard to break and it also reduced the threshing efficiency significantly.

4. CONCLUSIONS

1. Cylinder speed, concave clearance and moisture content play important role in affecting threshed seed quality of chickpea. Among all these machine and crop parameters, cylinder speed is most important as germination per centage was maximum affected by cylinder speed flowed by moisture content.
2. Moisture content is very critical factor affecting thresher performance with respect to chickpea seed crop threshing.
3. The combination of 8.94 m/s: cylinder speed, 14 mm: concave clearance and 10 per cent: moisture content found optimum to yield high quality seed of chickpea and efficient threshing.

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Table 1. Performance indicators of chickpea seed crop threshing.

Parameter	Level	Visible Seed Breakage (%)		Electrical Conductivity (mS cm^{-1} g^{-1})		Germination (%)		Threshing Efficiency (%)	
		BG -1088	**BG -1103**	**BG-1088**	**BG-1103**	**BG-1088**	**BG-1103**	**BG-1088**	**BG-1103**
Cylinder Speed, m/s	**8.05**	4.008 (11.147)	3.374 (10.43)	0.6159 (0.47571)	0.46309 (0.37552)	66.306 (54.654)	67.944 (55.681)	82.673 (65.668)	82.114 (65.307)
	8.94	6.720 (14.278)	4.677 (11.98)	0.8229 (0.58895)	0.65849 (0.49183)	65.056 (53.943)	68.167 (55.895)	92.73 (77.152)	91.581 (75.830)
	13.42	50.032 (44.292)	18.193 (24.35)	1.1695 (0.74864)	0.86188 (0.59193)	33.944 (35.648)	42.389 (40.885)	95.085 (80.951)	93.378 (78.169)
CL, mm	**12**	26.751 (28.853)	13.155 (19.93)	1.1287 (0.74744)	0.88112 (0.62172)	48.472 (44.084)	51.833 (46.06)	91.165 (76.547)	91.233 (76.191)
	14	20.549 (23.585)	7.901 (15.06)	0.8124 (0.58010)	0.56566 (0.43720)	57.417 (49.457)	61.333 (51.87)	91.599 (75.204)	89.934 (73.101)
	16	13.459 (17.878)	5.187 (12.26)	0.6673 (0.50335)	0.53669 (0.42424)	59.417 (50.674)	65.333 (54.249)	87.725 (70.656)	85.906 (68.935)
MC, %	**8**	16.541 (20.565)	7.200 (14.09)	0.9853 (0.67105)	0.80928 (0.58002)	54.056 (47.422)	58.139 (49.891)	83.209 (66.129)	81.949 (65.189)
	10	21.457 (24.358)	8.614 (15.61)	0.8358 (0.59282)	0.6341 (0.48047)	58.417 (50.121)	63.806 (53.384)	94.309 (79.340)	92.888 (77.333)
	12	22.761 (25.393)	10.43 (17.55)	0.7872 (0.56702)	0.54009 (0.42267)	52.833 (46.67)	56.556 (48.904)	92.971 (76.938)	92.236 (75.705)
CD at 5%		0.434	0.264	0.01978	0.01744	0.58676	0.50082	0.55734	0.54441

* Figures in parenthesis indicate arc sine transformed values.

Table 2. ANOVA for the chickpea threshing by plot thresher performance.

BG-1088 (*Kabuli*)					
Source of Variations	DF	F-Value			
		BR	EC	GR	EFF
Replication	3	2.01	1.33	0.65	0.34
RPM	2	14653.65***	434.60***	2681.61***	1241.30***
CL	2	1270.55***	315.76***	283.12***	165.47***
RPM*CL	4	103.55***	25.56***	126.30***	82.15***
MC	2	272.44***	59.48***	75.84***	1083.54***
RPM*MC	4	43.12***	3.06*	11.29***	26.10***
CL*MC	4	17.79***	2.25	3.65**	51.94***
RPM*CL*MC	8	27.80***	2.19	4.66***	9.99***
Error	78				
BG-1103 (*Desi*)					
Source of Variations	DF	F-Value			
		BR	EC	GR	EFF
Replication	3	1.85	0.29	0.64	2.21
RPM	2	7141.24***	376.28***	2429.28***	1001.72***
CL	2	1714.61***	317.95***	560.86***	266.49***
RPM*CL	4	207.28***	47.96***	137.47***	149.59***
MC	2	342.00***	165.08***	175.05***	1025.31***
RPM*MC	4	3.78**	0.80	8.50***	19.10***
CL*MC	4	2.13	2.77	2.56*	68.47***
RPM*CL*MC	8	1.25	1.900	2.07	26.08***
Error	78				

RPM (Rotation Per Minute; Cylinder Speed), CL (Clearance), MC (Moisture content), BR (Visible Breakage), EC (Electrical Conductivity; Invisible Breakage), GR (Germination Percentage), EFF (Threshing Efficiency). *, ** and *** indicate significant at 0.10, 0.05 and 0.01 level of probability, respectively.