Modeling of wheat crop harvesting losses

S. K. Patel[1], B. P. Varshney[2]

(1. *Asstt. Professor, KVK, Anand Agricultural University, Dahod, Gujarat, India*; 2. *Rt. Prof. GBPUAT, Pantnagar, India*)

Abstract: Recognition of effective factors and using suitable mechanism of crop harvesting can reduce seed losses to an acceptable amount. To investigate wheat crop losses due to seed moisture content and the speed of combine harvester at seed harvest time, research was carried out in G.B.P.U.A. & T., Pantnagar in 2003. This study included three seed moisture contents (10%, 15% and 20%) and three combine working speeds (1, 2 and 2.5 km/h) based on split plot by using a randomized block design with three replications. Finally combine working speed of 1.5 km/h and 9.16% crop moisture content was suitable for harvesting wheat crop. Stepwise regression technique was used to develop combine losses, seed breakage, performance and threshing efficiency models from field data. The r^2 value for seed breakage, performance efficiency and threshing efficiency were 0.888, 0.676 and 0.803, respectively.

Keywords: multiple regressions, plot combine harvester, stepwise regression, seed breakage

Citation: Patel, S. K., and B. P. Varshney. 2014. Modeling of wheat crop harvesting losses. Agric Eng Int: CIGR Journal, 16(2): 97−102.

1 Introduction

In India today, the rate of food production is matching well with the population growth due to the consistent efforts made by the bio-scientists like agronomists, plant breeders, plant physiologists and agricultural engineers. Together, they have considerable impact in increasing the yield per unit area through varietal development using high inputs and assuming the high degree of risk of imported varietal technology. The yield potential of most of crops has more or less stagnated. But, the population in India is growing at an alarming rate of around 1.93 percent per year. This makes it necessary that the food grain production should also increase at least at the same rate or faster to meet out the total food demand of the masses. Thus, the use of the experimental field plot machinery may contribute considerably in pushing the yield towards the genetic maximum potential of the crop (Segler, 1977). Hence, mechanization of field operations on experimental plots is considered a key input to the agricultural research. However, use of machine under optimum set of condition may help in better results.

Singh et al. (1975) studied the effect of moisture content and forward speed on the field performance of a combine harvester for wheat. It was found that visible grain damage decreased with increase in moisture up to 20 percent. It was also found that in the moisture range of 7.84% to 11.70% (dry basis), the shatter loss was predominant whereas other component losses were insignificant. It was observed that increasing in forward speed; the total loss increased rapidly due to the over-loading of the straw rack at a result high feed rate and increased threshing loss as a result of higher impact action of the reel bats. Lotey and Singh (1985) studied the effect of moisture content on threshing losses incurred in harvesting the wheat. They found that the threshing loss increased linearly with the decrease in grain moisture content from 15.0% to 8.0% (dry basis) and increased rapidly at a high rate for grain moisture content of 8.0% to 6.5%. Bukhari et al. (1991) analyzed the influence of timing and date of harvest on wheat grain losses.

The highest grain losses were observed when the wheat harvesting was performed between 1600 and 2000

Received date: 2010-06-16 **Accepted date:** 2014-04-24

Corresponding author: S. K. Patel, Asstt. Professor, KVK, Anand Agricultural University, Dahod, Gujarat, India. Email: sppiari@gmail.com.

hours and lowest between 800 and 1,200 hours for all the varieties, at various intervals. The moisture content of grains linearly decreased in relation to increase in harvesting intervals. Further, decrease in moisture content of grains, total grain losses increased.

Glancey (1997) developed a model for the analysis of loss from the header of a pod stripper combine. An orthogonal transformation and regression technique was used to determine the effects of combine forward speed and picking reel speed on the header losses in green peas. The results indicated that there was an optimal speed combination of 2.1 km/h for minimum pod stripper header loss of 2.03% of the pea yield. Verma et al. (2000) observed the effect of wheat moisture content on combine losses. It was found that higher moisture content at the time of harvesting had given the minimum cutter bar loss. High moisture content had given the higher cylinder loss. A crop harvested at higher moisture content had lesser rack and sieve losses.

Rod et al. (2013) conducted experiment to determine the berseem clover seed losses due to seed moisture content and the speed of combine harvester at seed harvest time. Research was carried out in Khuzestan Province in 2011. This study included three seed moisture contents (10%, 15% and 20%) and three combine working speeds (1, 2 and 2.5 km/h) with three replications. Results were shown that reduction of seed moisture content from 20% to 10%, seed losses on platform increased from 4.61% to 8.11%. Interaction between combine working speed and seed moisture content showed 4.53% (65.98 kg/ha) losses where combine working speed was 1.0 km/h with 20% seed moisture content and the highest was 11.66% (169.2 kg/ha) using 2.5 km/h and 10% moisture content. Finally combine working speed of 2 km/h and 15% seed moisture content were suitable for harvesting berseem clover seed.

Since seed moisture content at harvest time and working speed are the affective factors on the amount of seed losses with combine-harvester, it is necessary to investigate the technical and economical studies on the effect of seed moisture content at harvest time, working speed in losses amount and losses at harvest, so the reduction of the seed losses at harvest time can encourage the farmers to increase the production. Keeping above in view, a study was undertaken with the objective to develop multiple regression models for harvesting of wheat crop at different forward speed of operations and moisture content of crops. Information from these models could be used to design control strategic for maximizing harvest yield and minimizing seed breakage.

2 Materials and methods

The performance of a plot combine was evaluated on wheat crop at Crop Research Centre of GBPUAT, Pantnagar with three levels of speed (1.0, 1.5 and 2.0 km/h) and three levels of moisture content (9.16%, 10.35% and 11.40%, dry basis) (Patel and Varshney, 2007; Rod et al., 2013). The range of the forward speed was kept close due to small plot size of agronomical trials. The ranges of moisture content were very close because the authors want to identify the proper harvesting time of the wheat crop. The plot combine harvester manufactured by M/S Wintersteiger, Austria was used for this experiment (Figure 1). It has been designed specially for experimental plots to harvest, thresh and clean the grain of different cereal crops in one operation. The cutting width of the machine is 1.50 m, which is suitable for breeder's plot. The reel index should be 1.25 to 1.50 under most conditions in upright crops (Goss et al., 1958). In this experiment the reel index (1.25) and cylinder speed (625 rpm) were kept constant.

Figure 1 Plot combine harvester

In this study authors tried to examine the operational speed on the performance of plot combine speed not on the cylinder speed of the combine harvester. That's why cylinder speed was kept constant. The different losses, grain breakage, performance efficiency and threshing efficiency were determined to evaluate the performance of plot combine. For the experiment harvesting was carried out at three different times (Patel and Varshney, 2007) i.e. 6.00 hours, 10.00 hours and 13.00 hours to ensure variation in moisture content of crop. Moisture content of the crop residue was determined by oven dry method.

The pre-harvest loss was determined at three randomly selected places from the area selected for test run of 5m. Three samples were collected in one square meter area in direction of travel and all the loose grains and complete ear heads fallen in the area before the combining were picked up manually without vibrating the plants. Thereafter, analysis was done for determining the pre-harvest loss in the plot. The cutters bar (header) losses were determined at three randomly selected places from test area. The loose grains and complete and incomplete ear heads fallen on an area of one square meter were collected. The same procedure was repeated for each experiment and all replications. For determining shaker and sieve losses, the straw and chaff afflux from the plot combine were collected separately. To collect the straw and chaff leaving the machines, two cloths (10 m × 2 m) were suspended on available mountings at rear of the machine, i.e., one for the shaker and the other for the sieve. The plot combine was operated through a test run of 5 m length at different forward speed. The threshed and unthreshed grains of the samples collected from tank, shaker as well as sieve were separated and weighed. The same procedure was repeated for each replication and calculations were done to calculate cutter bar loss, cylinder loss, shaker loss, sieve loss, seed breakage, performance efficiency and threshing efficiency (Patel, 2003).

Performance efficiency (%) = Total grain in the tank (g)×100/Gross yield (g)

Threshing efficiency (%) = Total threshed grain (g) × 100/Gross yield (g)

The method of stepwise regression technique was used to model. For regression model moisture content of crop was kept first variable and operational speed was kept second variable.

$$Y(\%) = \exp\left(b_0+b_1v+b_2m\right)$$

where, Y = observed parameters i.e. Cutter bar loss, cylinder loss, straw walker loss, sieve loss, total loss, seed breakage, performance efficiency and threshing efficiency, %; v = forward speed, km/h; m = moisture content of crop, %.

3 Results

The method of stepwise addition and deletion of variables was used to allow for large number of variables and to permit all variable combinations to account for the variation in the dependent variable (Singh and Linvill, 1977; Chandel, 2004). The best fit of multiple regressions (linear or exponential) was used. Exponential model calculation was done after transforming the estimated value of the dependent variable.

3.1 Effect of crop moisture content and speed on seed losses and seed breakage

The cutter bar loss was observed to be 0.19%, 0.26% and 0.58% at 1.0, 1.5 and 2.0 km/h, respectively. Similarly, at 10.35% moisture content, it was calculated as 0.32%, 0.41% and 0.67% at 1.0, 1.5 and 2.0 km/h, respectively. Further, at 9.16% moisture content this loss was 0.57%, 0.58% and 0.87% at the above three levels of speeds, respectively (Table 1). The cylinder loss was highest (8.86%) at 1.0 km/h speed for 11.40% crop moisture content. This was due to the fact that at 1.0 km/h, the cylinder speed was also quite low, which was not at all sufficient for threshing the grain. The cylinder loss was lowest (0.50%) at 9.16% moisture content and 2 km/h. The straw walker loss was highest (1.81%) at 1.0 km/h for 11.40% moisture content of the crop. Whereas, at 1.5 and 2.0 km/h, it was 1.45% and 1.69%. The minimum shaker loss was 1.45% and 0.75% at 11.40% and 10.35% moisture content, respectively, for 1.5 km/h. However, the minimum shaker loss was 0.54% at 2.0 km/h for 9.16% moisture content. The sieve loss was minimum (0.34%) at 1.5 km/h and 9.16% moisture content followed by 1.0 and 2.0 km/h for other moisture contents. The sieve loss was maximum (0.93%) for 11.40% moisture content at

1.0 km/h. The total losses were minimum (2.17%) at 1.5 km/h operational speed for 9.16% moisture content and maximum (11.73%) at 1.0 km/h with 11.40% moisture content of the crop. The mechanical grain breakage ranged from 0.09% to 0.15%, 0.12% to 0.27% and 0.13% to 0.35% at 11.40%, 10.35% and 9.16% moisture content, respectively. The grain breakage was minimum (0.09%) at 1.0 km/h with 11.04% moisture content and maximum (0.35%) at 9.16% moisture content for 2.0 km/h operational speed. The performance efficiency was maximum (97.88%) at 9.16% moisture content with 1.5 km/h speed followed by 2.0 and 1.0 km/h at the same moisture content. The threshing efficiency increased with increasing speed as well as moisture content of the crop. It was maximum (99.19%) at 2.0 km/h for 9.16% moisture content followed by 10.30% and 11.40% moisture content.

The best fit of regression for cylinder loss, straw-walker loss, sieve and total loss was exponential model while linear model for cutter bar loss was observed. The general characteristics caused by various levels of each variable of the main effects are given in Table 1. Cutter bar loss was increased with both increase of operational speed and decrease of moisture content. On the basis of total losses, grain breakage, performance efficiency and threshing efficiency, the operational speed of 1.5 km/h gave better results at 9.16% moisture content of crop than other two operational speeds. However, the grain breakage was found a bit higher at 1.5 km/h in comparison to 1.0 km/h. The estimated relationship for cutter bar loss, cylinder loss, shaker loss, sieve loss and total losses are shown in Table 2 together with regression coefficients and other statistics. For cutter bar loss plot combine harvester speed was more effective than moisture content of crop while cylinder loss and shaker loss moisture content of crop was more effective than plot combine harvester speed. From the model cutter bar loss can be minimized if operational speed of combine was kept low. In the final equation both variables were appeared. In final equation of sieve loss and total loss only moisture content of crop has appeared i.e. harvesting speed did not affect sieve loss and total loss. Plot combine speed did not affect total combine loss.

Table 1 Main effects means and standard deviation caused by various levels of each variable

Parameters	Speed /km h^{-1}	Moisture content of crop/%			Standard deviation
		11.4	10.35	9.16	
Cutter bal loss/%	1.0	0.19	0.32	0.57	0.190722
	1.5	0.26	0.41	0.58	0.160033
	2.0	0.58	0.67	0.87	0.149039
Cylinder loss/%	1.0	8.80	3.55	1.42	3.798299
	1.5	4.77	1.14	0.62	2.264799
	2.0	4.87	1.04	0.50	2.379445
Shaker loss/%	1.0	1.81	1.36	0.84	0.482465
	1.5	1.45	0.75	0.58	0.46513
	2.0	1.69	0.94	0.54	0.582067
Sieve loss/%	1.0	0.93	0.84	0.42	0.272306
	1.5	0.67	0.41	0.34	0.174985
	2.0	0.82	0.50	0.51	0.182767
Total loss/%	1.0	11.73	6.07	3.25	4.317544
	1.5	7.16	2.70	2.12	2.76097
	2.0	7.96	3.16	2.42	3.006545
Seed breakage/%	1.0	0.09	0.12	0.13	0.019058
	1.5	0.09	0.17	0.19	0.052474
	2.0	0.15	0.27	0.35	0.100527
Performance efficiency/%	1.0	88.27	93.93	96.73	4.306667
	1.5	92.84	97.30	97.88	2.76097
	2.0	92.04	96.84	97.58	3.006545
Threshing efficiency/%	1.0	89.36	94.77	97.56	4.170208
	1.5	94.59	98.36	99.00	2.38594
	2.0	94.61	98.55	99.19	2.479624

Table 2 Parameter values and regression statistics for plot combine losses

Regression coefficients, b_i	s. e.*	Standardized coefficients, β	Sig. level	Regression statistics
Cutter bar loss, % = $b_0+b_1v+b_2m$				
b_0 = 1.498	0.291	-	0.002	R^2 = 0.914, R^2_{adj}=0.886, $S.E.$ = 0.074
b_1 = 0.347	0.060	0.691	0.001	r^2 = 0.888, r^2_{adj}=0.851,
b_2 = -0.148	0.027	-0.661	0.001	$S.E._{cal}$= 0.1805
Cylinder loss, % = exp($b_0+b_1m+b_2v$)				
b_0 = -7.260	1.296	-	0.001	r^2 = 0.922, r^2_{adj}=0.896, $S.E._{cal}$= 0.3272
b_1 = 0.908	0.119	0.869	0.000	R^2 = 0.659, R^2_{adj}=0.610,
b_2 = -0.954	0.267	-0.408	0.012	$S.E.$ = 1.7418
Shaker loss, % = exp(b_0+b_1m)				
b_0 = -4.305	0.816	-	0.001	r^2 = 0.801, r^2_{adj}=0.773, $S.E._{cal}$= 0.2166
b_1 = 0.419	0.079	0.895	0.001	R^2 = 0.799, R^2_{adj}=0.770, $S.E.$ = 0.230
Sieve loss, % = exp(b_0+b_1m)				
b_0 = -3.537	0.921	-	0.006	r^2 = 0.601, r^2_{adj}=0.544, S. E.$_{cal}$= 0.2444
b_1 = 0.289	0.089	0.775	0.014	R^2 = 0.585, R^2_{adj}=0.526, $S.E.$ = 0.1489
Total loss, % = exp(b_0+b_1m)				
b_0 = -4.133	1.235	-	0.012	r^2 = 0.748, r^2_{adj}=0.712, $S.E._{cal}$= 0.3277
b_1 = 0.544	0.0119	0.865	0.003	R^2 = 0.684, R^2_{adj}=0.639, $S.E.$ = 1.9722

Note: *s.e.- Standard error of regression coefficient, b_i; R^2-Notation used for linear multiple coefficient of determination; R^2_{adj}-Multiple coefficient of determination adjusted by degree of freedom; r^2- Notation used for exponential multiple coefficient of determination; r^2_{adj}- exponential Multiple coefficient of determination adjusted by degree of freedom.

For minimum combine loss optimum crop moisture content must be exist at the time of harvesting. The seed breakage includes those which could be observed by necked eyes. The estimated relational for seed breakage was exponential. The regression coefficient and other statistic for this model are shown in Table 3. $S.E._{cal}$, r^2 and r^2_{cal} were calculated after transforming the estimated value of the dependent variable from the exponential. These values of r^2, r^2_{cal} and $S.E._{cal}$ for the exponential model were better than R^2, R^2_{cal} and $S.E.$ values for linear models. The residual analysis of the transformed exponential model did not show any marked difference between the two. In seed breakage model the effect of harvesting speed and moisture content of crop are always positive, which indicates that an increase in harvesting speed and moisture content of crop will increase seed breakage.

Table 3 Parameter values and regression statistics for seed breakage, performance efficiency and threshing efficiency

Regression coefficients, b_i	s. e.*	Standardized coefficients, β	Sig. level	Regression statistics
Seed breakage, % = exp(b_0+b_1v+b_2m)				
b_0 = -0.037	0.707	-	0.960	r^2 = 0.888, r^2_{adj}=0.851, $S.E._{cal}$= 0.1784
b_1 = 0.771	0.146	0.722	0.002	R^2 = 0.830, R^2_{adj}=0.773,
b_2 = -0.288	0.065	-0.606	0.004	$S.E.$ = 0.0413
Performance efficiency, % = exp(b_0+b_1m)				
b_0 = 4.858	0.081	-	0.000	R^2 = 0.684, R^2_{adj}=0.638, $S.E.$ = 1.9741
b_1 = -0.0298	0.008	-0.822	0.006	r^2 = 0.676, r^2_{adj}=0.630, $S.E._{cal}$= 0.0214
Threshing efficiency, % = exp(b_0+b_1m+b_2v)				
b_0 = 4.783	0.069	-	0.000	R^2 = 0.810, R^2_{adj}=0.747,
b_1 = -0.0265	0.006	-0.757	0.006	$S.E.$ = 1.6183 r^2 = 0.803, r^2_{adj}=0.737,
b_2 = 0.0376	0.014	0.478	0.039	$S.E._{cal}$= 0.0175

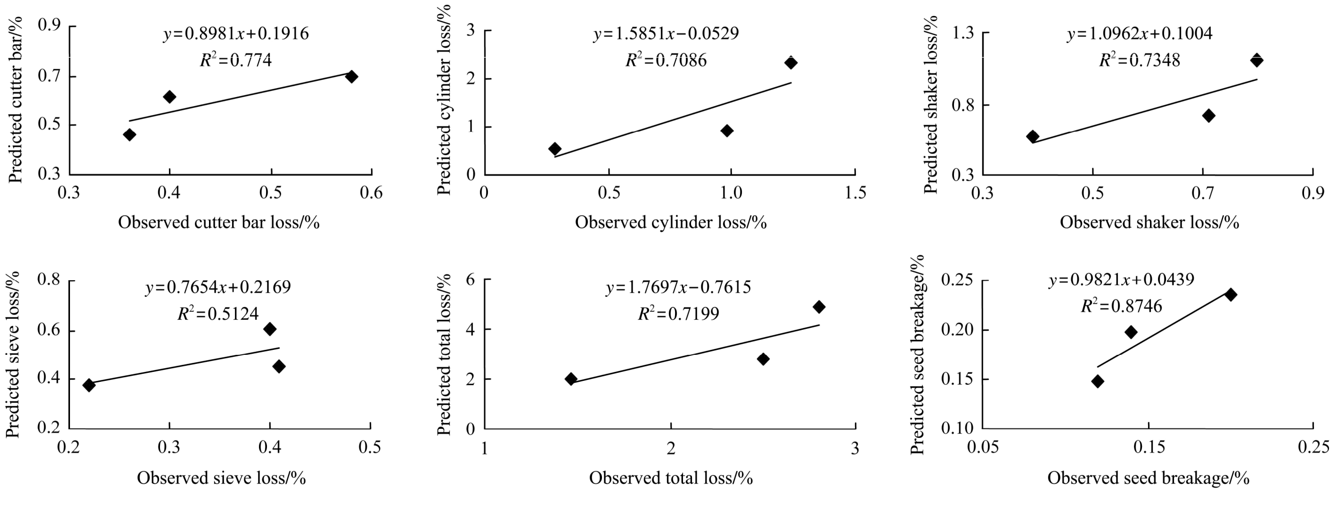
Note: **s.e.- Standard error of regression coefficient, b_i; R^2-Notation used for linear multiple coefficient of determination; R^2_{adj}-Multiple coefficient of determination adjusted by degree of freedom; r^2- Notation used for exponential multiple coefficient of determination; r^2_{adj}- exponential Multiple coefficient of determination adjusted by degree of freedom.

3.2 Effect of crop moisture content and speed on performance and threshing efficiency

Stepwise regression was used to determine the effective variables for performance efficiency and threshing efficiency. The best estimated relationships for performance and threshing efficiency were linear and regression coefficients are given in Table 3. In final equation of performance efficiency only crop moisture content has appeared. Plot Combine speed did not affect performance efficiency. R^2, R^2_{cal} and $S.E.$ Values for the linear model were better than r^2, r^2_{cal} and $S.E._{cal}$ values for exponential model. The most effective variable for threshing efficiency was crop moisture content. However, plot combine harvester speed also existed in final model. The residual analysis of the linear model and transformed exponential model for threshing efficiency did not show any marked difference between the two. Performance and threshing efficiency model has always positive effect with crop moisture content.

3.3 Model validation

Regression equations for plot combine harvester were validated with data collected during the experiment. The R^2 calculated from observed and predicted value were 0.77, 0.86, 0.76, 0.77, 0.89, 0.72, 0.84 and 0.76 for cutter bar loss, cylinder loss, shaker loss, total loss, seed breakage, performance efficiency and threshing efficiency respectively. Figure 2 is a plot of observed value and predicted value for performance of plot combine harvester from the models in Table 2 and Table 3.



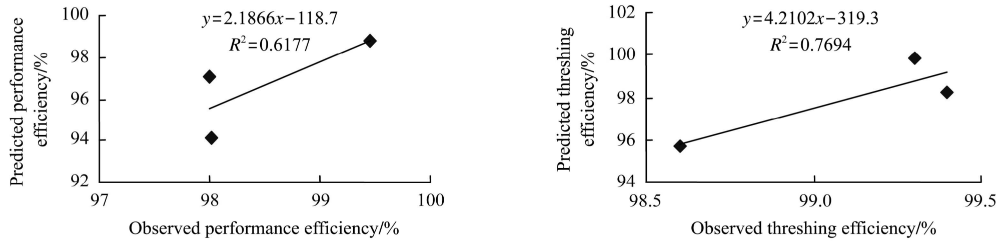


Figure 2 Observed versus predicted relationship of different model

4 Conclusions

Crop moisture content and operational speed of Plot Combine Harvester were the major variables in the regression model. The value for coefficient of determination for cutter bar loss, cylinder loss, shaker loss, sieve loss and total loss were 0.914, 0.922, 0.801, 0.601 and 0.748 respectively. The best fit of regression model for seed breakage was exponential while for performance efficiency and threshing efficiency were linear. The r^2 value for seed breakage, performance efficiency and threshing efficiency were 0.888, 0.676 and 0.803 respectively. These models demonstrate quantitatively that careful adjustment of operational speed and crop moisture content is required during the harvesting period in order to reduce the total combine loss. This will allow one to minimize seed loss, seed breakage and better threshing efficiency because seed is costly input in agricultural program.

References

Bukhari, S., K. A. Ibupota, G. H. Jamro, and G. A. Khoro. 1991. Influence of timing and date of harvest on wheat grain losses. *Agricultural Mechanization in Asia,* 22(1): 56-58 and 62.

Chandel, S. R. S. 2004. *A Hand Book of Agricultural Statistics*. Achal Prakashan Mandir, Kanpur.

Glancey, J. L. 1997. Analysis of header loss from pod stripper combines in green peas. *Journal of Agricultural Engineering Research,* 68(1): 1-10.

Goss, J. R. and R. A. Kepner and L.G. Jones. 1958. Performance characteristics of the grain combine in barley. Agricultural Engineering, 39: 697-702, 711.

Lotey, J. S., and C. P. Singh. 1975. Studies on cutting force requirements and shattering losses incurred in harvesting of wheat. *Journal of Agricultural Engineering Research,* 12(3-4): 10-16.

Patel, S. K. 2003. *Performance evaluation of imported experimental multi-crop seed drill and plot combine harvester*. Unpublished Thesis, M. Tech., GBPUA&T, Pantnagar.

Patel, S. K., and B. P. Varshney. 2007. Effect of operational speed and moisture content of wheat crop on plot combine harvester. *Agricultural Mechanization in Asia, Africa and Latin America,* 38(4): 51-54&60.

Rod, N. M., M. A. Asoodar, and M. Rahnema. 2013. Effect of combine working speed and seed moisture content on berseem clover losses in khouzestan. *International Journal of Agriculture and Crop Sciences*, 5(4): 349-354.

Segler, G. 1977. Agricultural engineering in India and its importance for development. *Allied Science and Development* Vol. 9.

Singh, K. N., B. Singh, and T. N. Mishra. 1975. *Combine operation for minimum losses*. Department of Farm Machinery and Power Engg. Bulletin G. B. Pant University of Agric. and Tech., Pantnagar, U.A. 50 pp.

Singh, B., and D. E. Linvill. 1977. Determining the effect of pod and grain moisture content on threshing loss and damage of navy beans. *Transaction of the ASAE,* 20(2): 226-227 and 231.

Verma, R. B., S. K. Yadav, and A. K. Singh. 2000. *Effect of wheat varieties on combine losses*. Dissertation report, B. Tech. Department of Farm Machinery.