

Studies on Machine-Crop Parameters of an Axial Flow Thresher for Threshing Soybean

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Abstract

To study the effect of machine-crop variables on the performance, a threshing unit was fabricated and tested. The same threshing unit will be used for the proposed axial flow soybean combine harvester. A peg-tooth drum was used for the study. Four levels of drum speeds, three levels of feed rates and three levels of soybean moisture contents were studied. Test results indicated that the threshing efficiency varied from 98 to 100%. The grain damage and grain loss were less than 1 and 1.5% respectively at drum speeds of 600 to 700 rpm and 540 to 720 kg (plant)/h feed rates and at 14.34 to 22.77% (w.b.) seed moisture contents. The maximum power requirement was 2.29 kW at grain moisture content of 32.88% (w.b.) at a drum speed of 700 rpm. The best combination of feed rate, drum speed at 14.34% (w.b.) seed moisture content to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was 600 to 700 rpm drum speed (13.2 to 15.4 m/s) at a feed rate of 720 kg (plant)/h.

Keywords: Soybean, threshing, axial-flow, machine, threshing efficiency.

1. Introduction

In Thailand, soybean consumption is increasing every year. To meet the demand, Thailand had to import both grain and soybean cake of 340,000 tons in 1990 to nearly 1,600,000 tons in 2001. In 1993, domestic need of 611,000 tons increased to 812,000 tons in 1998 (OAE, 1999). Thai government gave a high priority to increase soybean production. The policy is to encourage farmers to increase the planting area under soybean.

At the moment, for harvesting of soybean in time no combine harvester is present in Thailand. Thus the design and development of an axial flow soybean combine harvester was undertaken. In order to increase soybean production, the development of a soybean combine harvester has therefore become of paramount importance. The threshing unit plays a key role in determining the performance of a combine harvester. The axial flow peg-tooth cylinder threshers are widely used in Thailand. Some of them are modified for use with a rice combine harvester. The number of threshers increased from 19,637 units in 1992 to 68,527 units in 1995 (OAE, 1995). These threshers can be used to thresh many kinds of cereal grains such as paddy, mungbean, and also soybean. Therefore, this research was conducted to study the effect of drum speed, feed rate, moisture content, and to determine the suitable values of these variables for efficient performance of soybean threshing unit.

2. Literature review

Several devices have been designed to evaluate the effect of impact velocity on soybean seed quality (Cain and Holmes, 1977; Bartsch et al, 1979; Paulsen et al., 1981). Cain and Holmes (1977) evaluated the impact damage to soybean seed as the result of a single high speed collision with a

steel plate and concluded that impact damage is dependent on both seed moisture content and the velocity of impact. Bartsch et al. (1979) reported that the threshing and conveying operations during harvest consist of dynamic events which often involve large momentum exchanges during collision of seeds with machine components and other seeds. Paulsen (1978) stated that the common cause of damage in all grain-handling studies is the particle velocity immediately before impact and the rigidity of the surface against which the impact occurs. The percentage of splits and fine material increased as the impact velocity increased and as the seed moisture decreased from 17 to 8% (w.b.). The seed that had low percentages of splits after impact also had high germination.

Nave (1979) reported that a seed producer must be concerned with maintaining threshing and separating efficiency while avoiding undue impact damage to the seed. Efforts to reduce threshing damage while increasing capacity have resulted in the development of rotary threshing equipment. Newberg et al. (1980) evaluated the damage to soybean caused by rotary and conventional threshing mechanisms. Three different combines (a single-rotor machine, a double-rotor machine, and a conventional raspbar cylinder machine) were tested under field conditions at four peripheral velocities. The percentage of splits were significantly higher for the conventional cylinder than for either the single or double-rotor threshing mechanisms at similar peripheral speeds. The percentage of splits increased as peripheral threshing speed increased for all three threshing mechanisms. However, the increase in splits was less with the rotary threshing mechanisms than the conventional cylinder threshing. The separation losses with the rotary combines were significantly higher at the slowest rotor speed. Dauda (2001) evaluated a manually operated cowpea thresher for small scale farmers in northern Nigeria. The threshing efficiency was 84.1 to 85.9% and seed damage was 1.8 to 2.3%. Vejasit (1991) compared the performance of the raspbar and peg-tooth threshing drums of an axial flow thresher for soybean crop. The results indicated that amount of grain retained on threshing unit for both cylinder at all cylinder speeds and feed rates were not significantly different. Rani et al. (2001) studied the plot combine to thresh seed crop of chickpea and stated that maximum threshing efficiency was 97.2% at 8.9% (w.b.) seed moisture content and at 10.1 m/s cylinder speed. Mesquita and Hanna (1995) reported that the force required to open a soybean pod was remarkably smaller than the force required to uproot plants and to detach pods from stem. They further reported that the estimated energy per ha required by blast wheel to be driven was slightly smaller than the estimated energy per ha required by threshing mechanism of conventional combines.

3. Materials and Methods

This study was carried out at AED (Agricultural Engineering Division), Department of Agriculture, Bangkok, Thailand. The soybean threshing unit was designed and fabricated (Figure 1). The threshing unit consisted mainly of a commercially available main frame, tray, threshing drum, concave, separating and cleaning unit, conveyor and power drive unit. It operates on the principle of axial flow movement of the material. The threshing mechanism consisted of a threshing drum which rotates inside a two section drum concave. The threshing drum was fixed with 96 peg-tooths, each peg was 12 mm in diameter and 60 mm in the length on open threshing drum with lock nut. The diameter and length of the threshing drum was 520 mm and 960 mm respectively. The concave was made of mild steel rods with spacing of 25 mm. The concave clearance between the threshing drum and concave was fixed at 40 mm. The power from a Ford 4-wheel (2-wheel drive) Model-6640 tractor P.T.O. was transmitted to the threshing drum by V-belts.



Figure1: Testing of developed soybean threshing unit

For this study, four drum speeds, three feed rates and three moisture contents were used. The four drum speeds; 400, 500, 600 and 700 rpm which were equivalent to a peripheral velocity of 8.80, 10.99, 13.19 and 15.39 m/s respectively, were used. The thresher was powered by a tractor PTO and the speed was set by tractor engine throttle. Three feed rates; 360, 540 and 720 kg (plant)/h were used. Material was loaded onto the tray and fed into the threshing unit. The average moisture content of grain (plant) used in this test was 32.88 (29.09)% (w.b.), 22.77 (18.72)% (w.b.) and 14.34 (16.78)% (w.b.). The most common soybean variety grown in Thailand, KKU-35, was used for testing. The crop was harvested by a traditional method. The moisture content of grain and plant was determined by oven dry method (ASAE, 1983). The average grain-straw ratio of the crop was 1.23. The threshing drum speed was measured by proximity switch with a 1-teeth iron sprocket attached with the threshing drum shaft near the slip ring of the torque transducer. Threshing drum speed was measured by using a digital tachometer with a proximity switch. In this experiment, the torque transducer with strain gage (KFG-2-350-D2-11) was used. A digital dynamic strain amplifier Dra-10-A was used to amplify the output signals received from the transducer. A personal computer was used to control the instrumentation system, transfer and analyze the data. The power requirement was calculated by using the torque and speed data.

The performance indicators used for the evaluation and observation were as follows (RNAM Test code, 1995): output capacity, threshing efficiency, grain damage, grain losses and power requirement. The performance tests of the soybean threshing were conducted at different moisture contents, drum speeds and feed rates by using a randomized complete block design (RCBD) of a 3x4x3 factorial experiment with three replications in each treatment and comparison between treatment means by least significance difference (LSD) at 5% level (Box et al., 1978; Gomez and Gomez, 1984).

4. Results and discussion

4.1 Capacity

Figure 2 shows the effect of drum speed on capacity at different feed rates and grain (plant) moisture contents. The results indicated that the capacity rapidly increased with an increase in drum speed for all feed rates and grain moisture contents. The maximum capacity was obtained at the highest feed rate of 720 kg (plant)/h, 14.34% (w.b.) grain moisture content and at a drum speed of 700 rpm. It was higher than other feed rates throughout the range of drum speeds and moisture contents

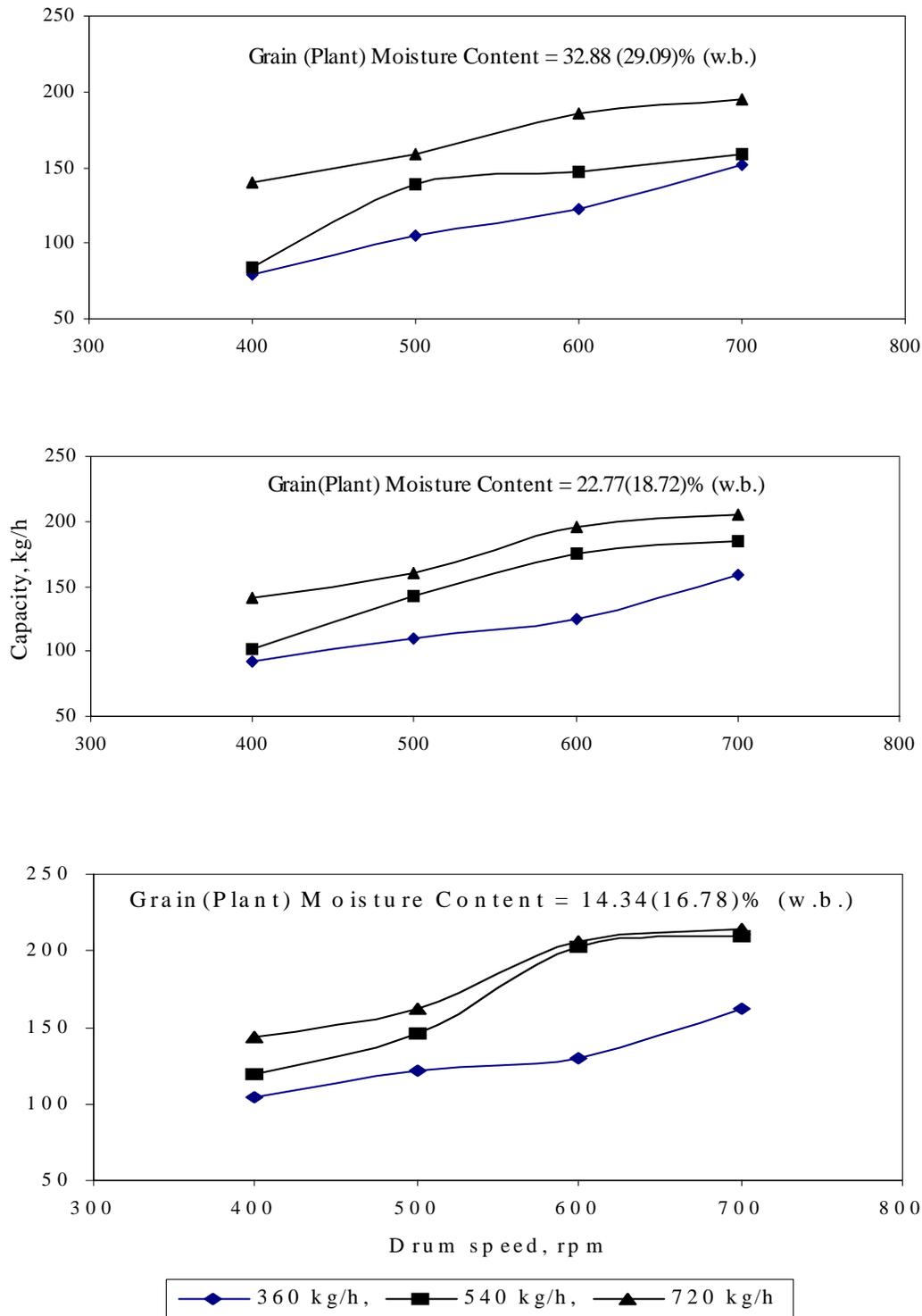


Figure 2: Effect of drum speed on capacity at different grain moisture contents and feed rates.

tested. The capacity at 14.34, 22.77 and 32.88% (w.b.) grain moisture content increased from 143.80 to 214.17, 141.79 to 204.74 and 139.70 to 195.30 kg/h respectively with increase in drum speed from 400 to 700 rpm at feed rate of 720 rpm. Test results showed that, as feed rate increased, capacity increased at all drum speeds for each moisture content. The capacity at 500, 600 and 700 rpm gradually increased when the feed rate was increased from 360 to 720 kg (plant)/h at 22.77 to 32.88% (w.b.) moisture content.

The analysis of variance of the main effects of the moisture content (A), feed rate (B) and drum speed (C) significantly affected capacity at 1% level (Table 1). Test results showed that the effect of drum speed and feed rate were the most significant. Among the first order interactions, moisture content and feed rate; feed rate and drum speed showed highly significant effect on capacity. Comparison among treatment means using the least significance difference (LSD) showed that at 720 kg (plant)/h feed rate, the capacity was not significantly different when moisture content changed from 14.34 to 22.77% (w.b.). The capacity at grain moisture content of 32.88, 22.77 and 14.34% (w.b.) was significantly different when feed rate was changed from 360 to 720 kg/h. The capacity at 500, 600 and 700 rpm drum speeds was not significantly different when the feed rate was varied from 360 to 720 kg(plant)/h feed rates. The capacity at 540 and 720 kg/h feed rates showed a similar trend and was not significantly different as drum speed was varied from of 600 to 700 rpm.

Table 1: ANOVA for the soybean threshing unit performances.

Source of variation	d.f.	F-value			
		Capacity	Threshing efficiency	Grain damage	Grain loss
Replication	2				
Moisture content (A)	2	33.97 **	3.92 *	37.15 **	52.03 **
Feed rate (B)	3	217.56**	3.90 *	16.11 **	3.94 *
Drum speed (C)	3	213.10**	58.78 **	18.39 **	25.93 **
AB	6	4.77 **	0.72 ns	4.51 **	0.07 ns
AC	6	1.28 ns	1.32 ns	3.35 **	3.13 **
BC	9	6.00 **	1.47 ns	2.85 *	1.39 ns
ABC	18	1.31 ns	0.84 ns	0.99 ns	1.55 ns
Error	94				

** , highly significant at 1% level; *, significant at 5% level ; ns, non significant; df, degrees of freedom

4.2 Grain damage

Figure 3 shows the effect of drum speed on the grain damage at different grain moisture contents and feed rates. The results indicated that the percentage of grain damage increased slightly with an increase in drum speed at 32.88% (w.b.) grain moisture content for feed rates of 360 to 720 kg/h. However, it decreased slightly with an increase in drum speed at the same grain moisture content for feed rates of 540 kg/h. At 14.34 to 22.77% (w.b.) grain moisture content, the grain damage was between 0.07 to 0.68% for all feed rates and drum speeds. The grain damage slightly decreased with an increase in feed rate. The grain damage increased as the grain moisture content increased from 14.34 to 32.88% (w.b.). However, the grain damage was less than 1.5% at all moisture contents, feed rates and drum speeds combination.

The analysis of variance of the main effects of moisture content, feed rate and drum speed significantly affected grain damage at the 1% level. Among the first order interactions; moisture

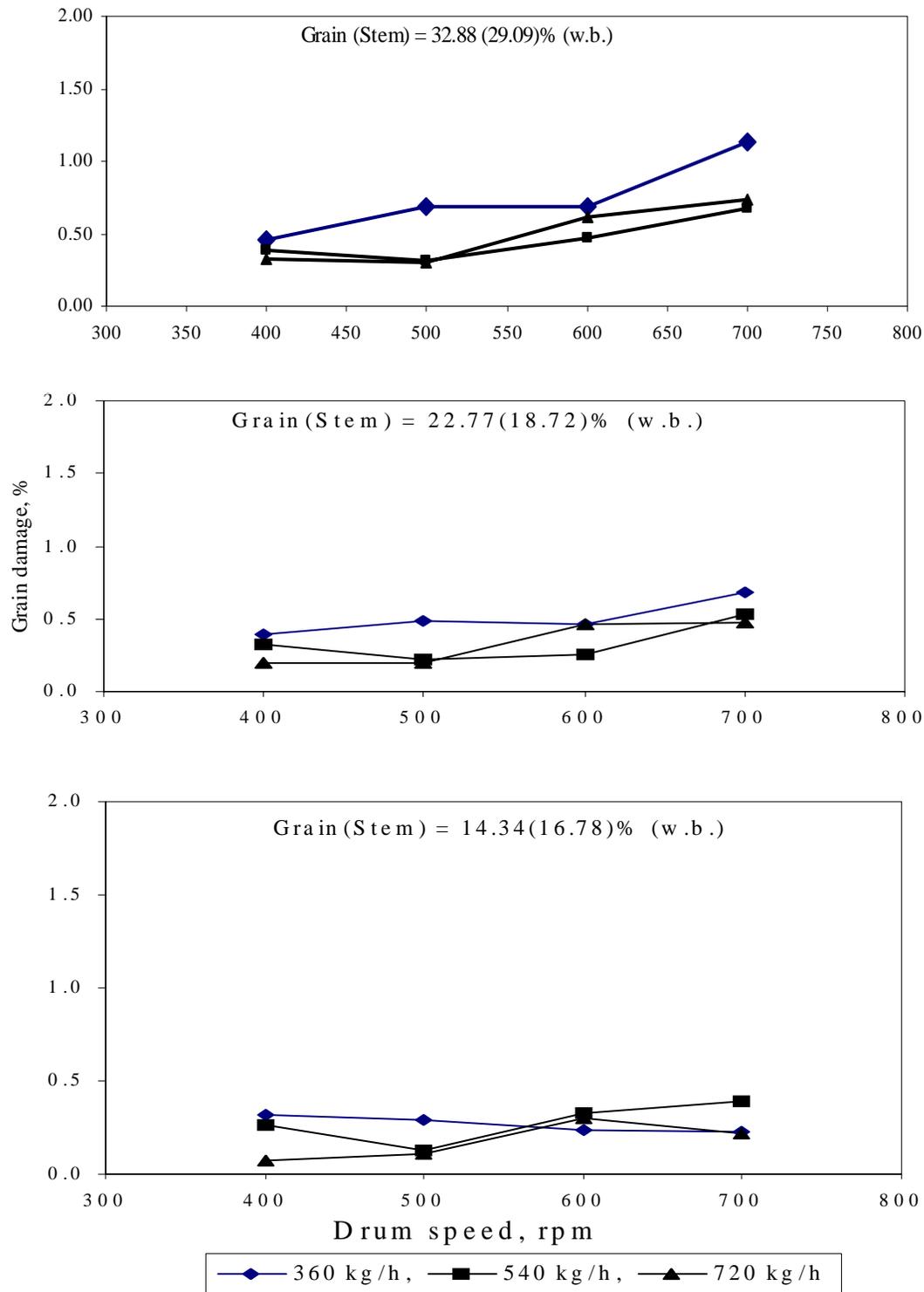


Figure 3: Effect of drum speed on grain damage at different grain moisture contents and feed rates.

content and feed rate, feed rate and drum speed, were significant. However, the interaction between moisture content and drum speed were not significant.

4.3 Threshing efficiency

Test results indicated that threshing efficiency was between 98.35 to 99.49% for the range of variables studied (Figure 4). These results were due to low pod cohesion at the range of soybean moisture content tested. This might have resulted into high threshing efficiency. Table 1 shows that drum speed, feed rate and moisture content significantly affected threshing efficiency at 1% and 5% levels respectively. Comparison among treatment means using LSD showed that at 14.34 to 32.88% (w.b.) with 600 to 700 rpm drum speed at feed rate of 720 kg (plant)/h, the threshing efficiency did not differ significantly.

4.4 Grain losses

Figure 5 shows the effect of drum speed on grain losses at different grain moisture contents and feed rates. Test results indicated that the grain losses at 32.88 and 22.77% (w.b.) rapidly decreased with increase in drum speed from 400 to 600 rpm and rapidly increased with further increase in drum speed from 600 to 700 rpm at all feed rates. At 14.34% (w.b.) grain moisture content, grain losses slightly decreased with an increase in drum speed from 400 to 700 rpm. Grain losses rapidly increased with increase in grain moisture content from 14.34 to 32.88% (w.b.) at all feed rates. The percentage grain loss was between 0.49 to 1.03% when the drum speed was varied from 500 to 600 rpm at the range of 14.34 to 22.77% (w.b.) grain moisture content.

Table 1 shows the analysis of variance of the main effects on grain loss at different moisture contents, feed rates and drum speeds at 1%, 5% and 1% levels of significance respectively. The interaction effects of moisture content and drum speed showed significant difference on grain loss at 1% level. Comparison between treatment means of grain loss showed that the grain loss did not differ significantly when grain moisture changed from 14.34 to 22.77% (w.b.) at 500 rpm and 600 rpm drum speeds. Grain losses at each grain moisture content of 32.88% (w.b.), 22.77% (w.b.), and 14.34% (w.b.) were not significantly different from 500 to 600 rpm drum speeds.

4.5 Power requirement

The power required of soybean threshing unit at different drum speeds, seed moisture contents and feed rates is shown in Figure. 6. It was observed that the power requirement of the threshing unit increased as the speed of threshing drum, feed rate and crop moisture content were increased. These increases were due to greater compression of the material and increased friction between crop material and threshing system. The average power requirement at 540 to 720 kg (plant)/h feed rates at 14.34% (w.b.) grain moisture content was between 0.89 to 1.85 kW, when the drum speed was increased from 500 to 700 rpm (11.00 to 15.40 m/s). However, it was observed that the maximum power required was 2.29 kW at grain moisture content of 32.88% and at the drum speed of 700 rpm.

5. Conclusions

- a) The moisture content, feed rate and threshing drum speed affected the output capacity, threshing efficiency, grain damage and grain losses during soybean threshing.

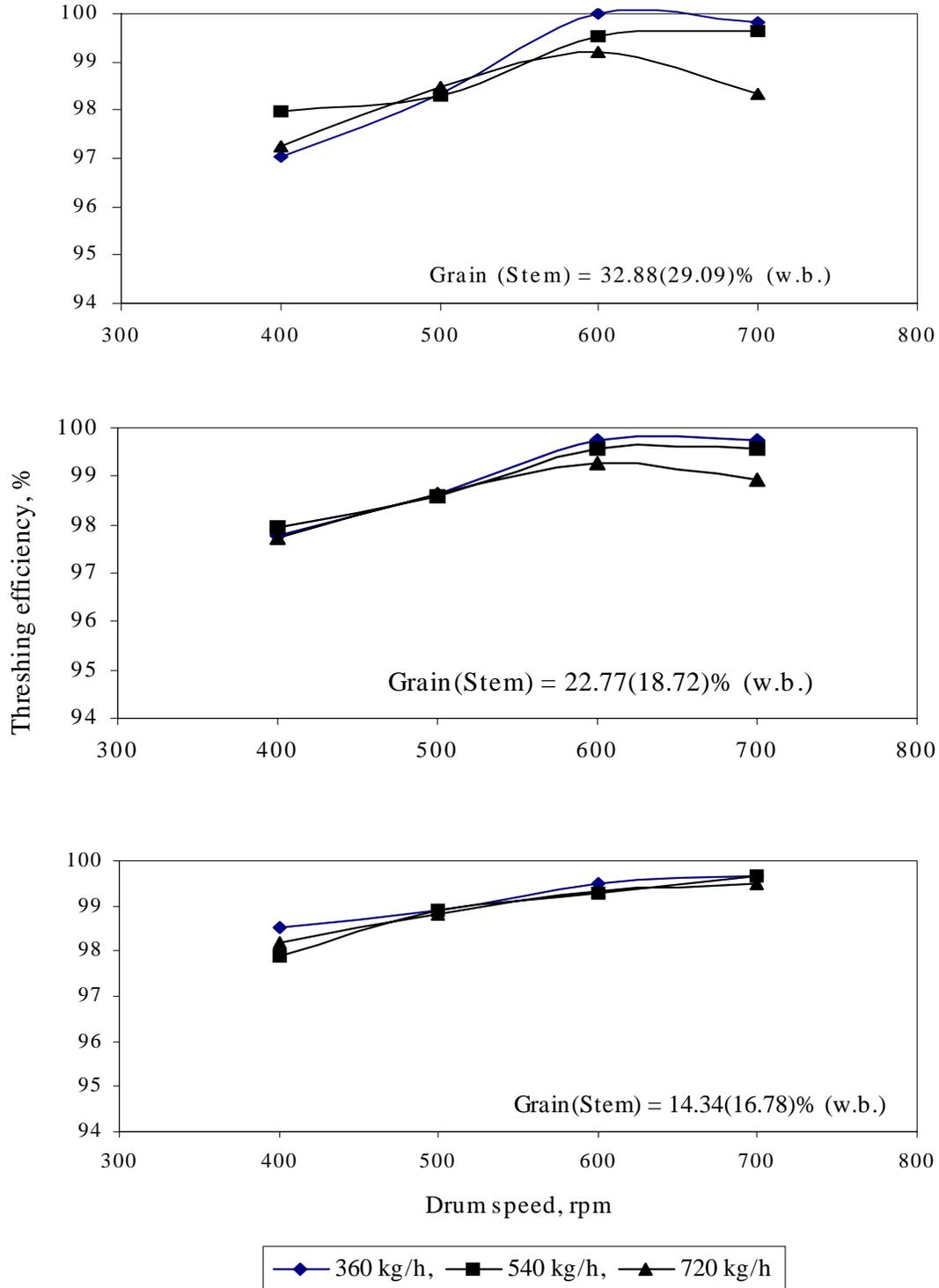


Figure 4: Effect of drum speed on threshing efficiency at different grain moisture contents and feed rates.

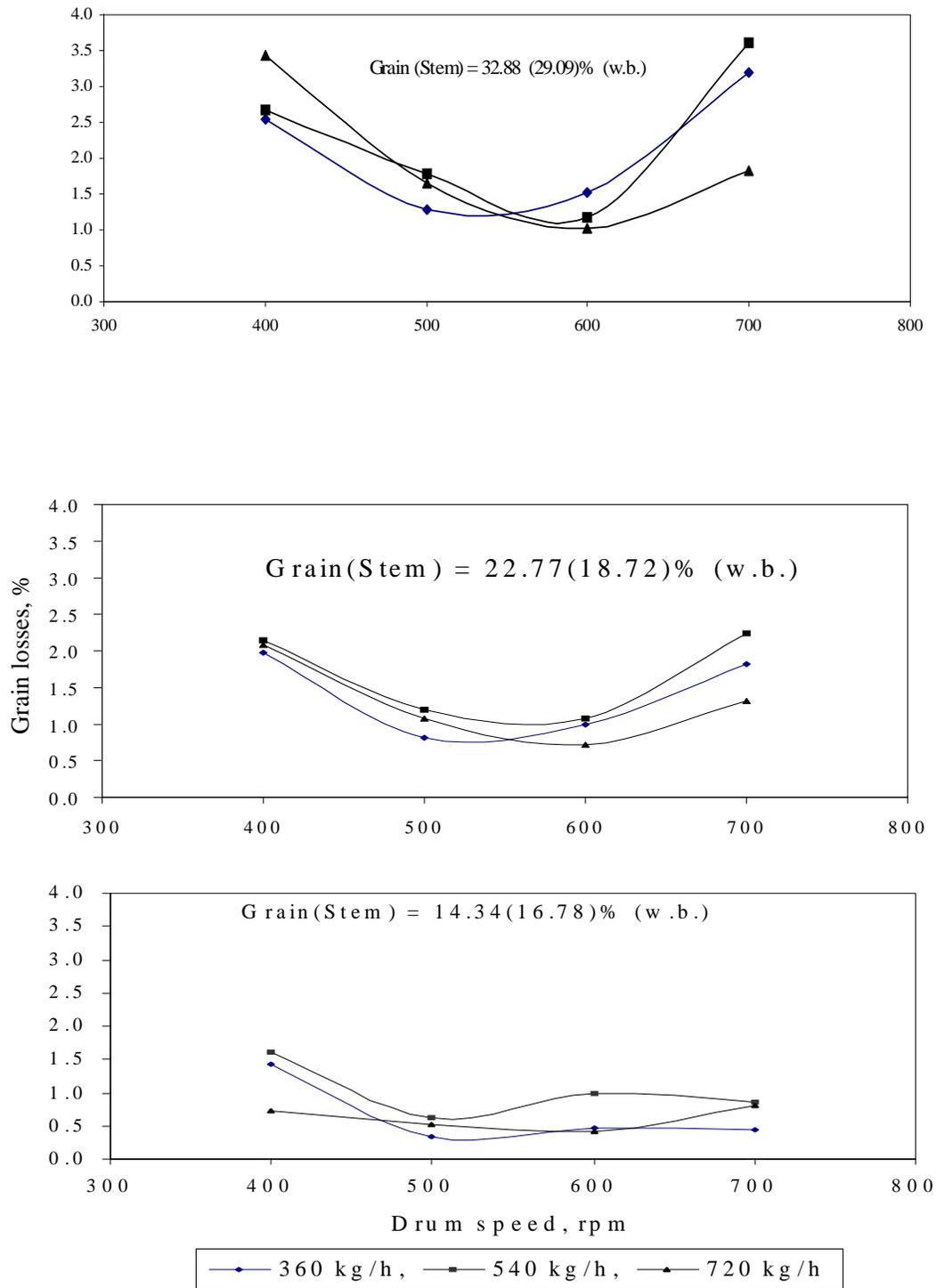


Figure 5: Effect of drum speed on grain losses at different grain moisture contents and feed rates.

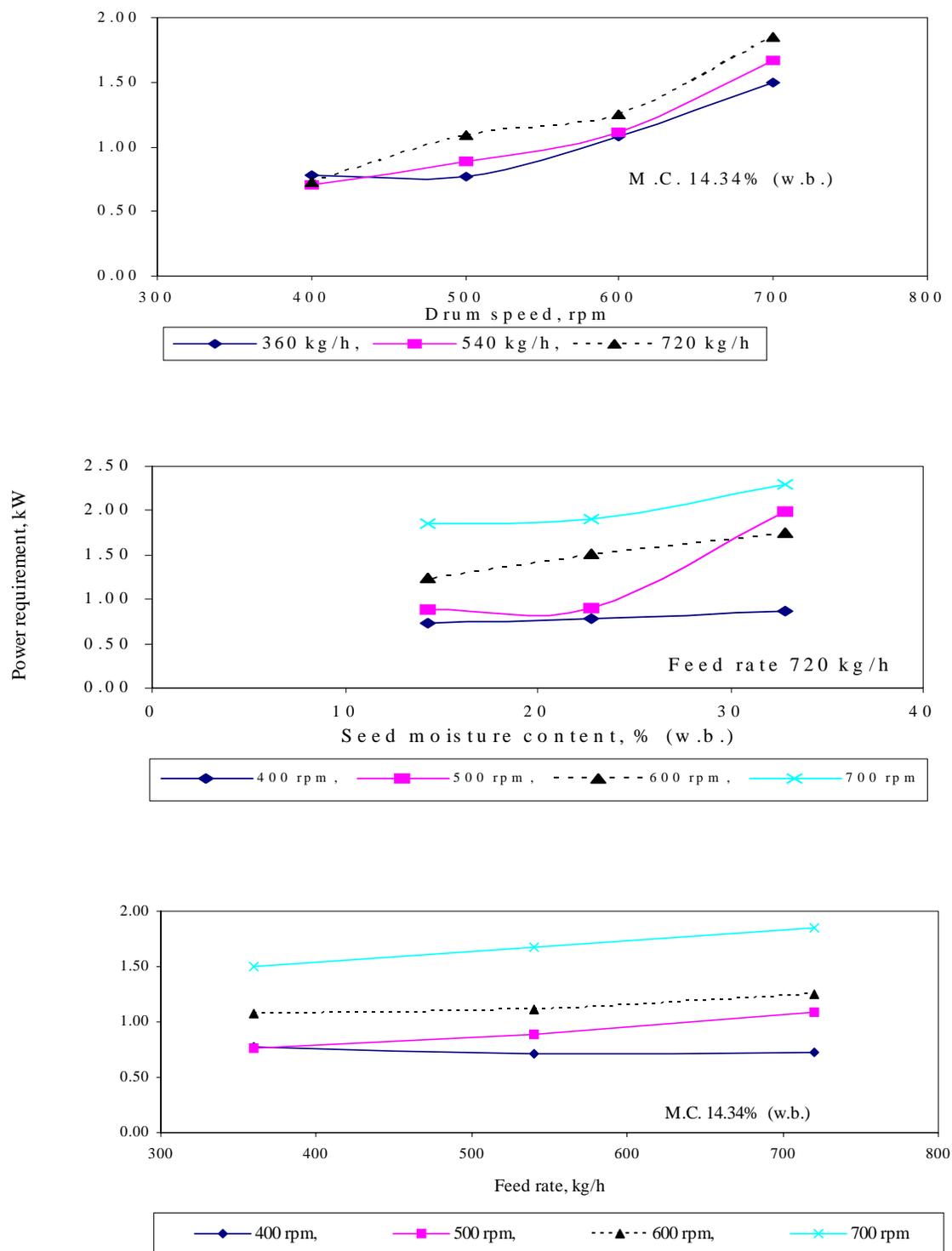


Figure 6: Effect of drum speed, seed moisture content and feed rate on power requirement of a soybean threshing unit.

- b) The capacity of the peg-tooth open threshing drum was between 144 to 214 kg/h at all drum speeds and feed rates. The threshing efficiency was found to be in the range of 98.00 to 100% for all moisture contents, feed rates and at drum speed range from 500 to 700 rpm. The grain damage was lower than 1%.
- c) It is recommended that the peg-tooth drum with speed range of 600 to 700 rpm (13.2 to 15.4 m/s) and feed rate of 540 to 720 kg (plant)/h be used for developing a threshing unit of a prototype soybean combine harvester.
- d) The output capacity, threshing efficiency, grain damage and grain loss at 700 rpm (15.4 m/s) drum speed and 720 kg (plant)/h feed rate were 214.17 kg/h, 99.49%, 0.22% and 0.80% respectively. These are within the acceptable range.
- e) The average power requirement was 1.85 kW at feed rate of 720 kg (plant)/h, 14.34% (w.b.) grain moisture content and drum speed of 700 rpm (15.4 m/s).
- f) The recommendations for the design of a soybean combine harvester - the drum speed should be from 13.2 to 15.4 m/s and the grain moisture content should be from 13 to 15% for efficient harvesting by a soybean combine harvester.

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