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Effect of Forward Speed and Vacuum Pressure on the Maize Seed Uniformity of Raised Bed Pneumatic Planter

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Abstract

The pneumatic planter is a precision agricultural tractor-mounted PTO-driven implement. It maintains uniformity in seed spacing with excellent precision. The pneumatic planter was capable for sowing of different seeds like wheat, soybean, all pulse seed and maize etc. Among these, the planter was tested with maize seed. The planter made two raised beds in a single pass and plant the seeds in four rows at 60 cm spacing. The bed was 80 and 60 cm wide from the bottom and top, respectively, and 15 cm deep. Its performance was evaluated at three levels of forward speed and vacuum pressure those were 2, 3, and 4 km/h and 3, 4 and 5 kPa, respectively. This study aimed to find out the variation in seed uniformity under differentforward speeds and pneumatic pressure. The size of experimental field was 50×40 m^2. The two-factor factorial design was used to prepare the layout of the experiment. The experiment was conducted inwell-pulverized soil at approximately 18% soil moisture content (wb). The optimized forward speed and pneumatic pressure were 3 km/h and 4 kPa, respectively. At these values, the seed uniformity was more than 94%. The effective field capacity, diesel consumption, and cost of operation were 0.76 ha/h, 4.7 l/h and ₹1200 /ha, respectively.

Keywords: *pneumatic planter, seed space uniformity, check row planting, missing seed index, multiple seed index.*

Introduction

Maize is one of the major crops for Indian Farmers grown in the Kharif season. However, it is grown in the winter (Rabi) season also. The statistics of the Food and Agricultural Organization (FAO) state that the in India estimated area of production, productivity and total production of maize in the year 2021 was 9.86 million hectares, 3.21 tonne per ha and 31.65 billion tonnes, respectively[1]. According to the report of the Indian Institute of Maize Research (IIMR), India ranks 4th and 7th in cultivation area and production, respectively, among maize-growing countries [2].The yield of top maize production counties like the USA and Canada is 11.11 and 10.00 per hectare[1]. It indicates that there are possibilities for increasing the yield per hectare. Therefore, it is necessary to improve the technology. Agronomical parameter like seed spacing plays a vital role in this. Maintaining the optimum spacing with uniformity increases the yield. To get the proper germination, IIMR recommends the optimized seed spacing and depth should be 60×20 cm, and 3.5 to 5 cm, respectively[1]. The traditional machine like seed drill cannot achieve constant longitudinal spacing. Because of the falling of seed at 1.2 to 1.5-meter height. In different delivery tubes of the seed drill or mechanical planter, the delivery of seeds starts at the same time but ends at a different time. Their striking with the wall of delivery tubes changes the path travel and thus the time. In each delivery tube, the seed falls at different times. Since the machine moves forward constantly and therefore, the seed drops at uneven spacing. The uneven time and spacing is mainly dependent on the height of seed fall. The uniform spacing can be achieved by reducing the height of seed fall. Apart from this, there are some other factors that affect the seed spacing. The seed-specific vacuum pressure, speed of forward travel, soil conditions and operator skill are some of them. High forward speed gives an improved field capacity but with inconsistent seed spacing. It was reported in a study that uneven seed spacing increases with the increased forward speed[3]. The seed spacing was more consistent at 3.6 km/h as compared to 5.4 and 7.2 km/h when tested with melon and cucumber seeds. It was investigated that vacuum pressure is dependent on the seed size, shape and weight[4]. The pressure higher than the required value may increase the multiple seed drops and decreases miss index. In concern to row crops, seed spacing and depth are important factors. The holes of a rotating plate of the seed metering mechanism equipped in a pneumatic planter carry single seeds. The seed cut-off is done by the space where the plate rotates in atmospheric pressure. The seed drops in the seeding tube and is placed in the soil. Theground wheel of a pneumatic planter is a braked wheel which generates the driving force to rotate the disk of the metering mechanism. Thus the speed of travel governs the disk speed rotation and maintains uniform seed spacing. Advantageously, precision in seed spacing, lower seed damage and a wide range of seeds with small variations in the metering unit[5, 6].It investigated the falling trajectory of seed using a high-speed camera[7]. This Lab experiment was conducted at different pressure (30, 40, 50 & 60 kPa) and forward speeds (3 to 4.5 km/h and 6 to 8.5 km/h), respectively, for maize and castor seed. They reported that at 3.0 to 4.5 km/h forward speed and 4.0 kPa vacuum pressuresthe seed feed rate was 98.31 and 80%, respectively, for castor and maize. Many researchers have investigated that there was a significant effect of speed and pressure on quality feed index, missing seed index and multiple seed index for cotton seed, maze and potato tuber etc [8, 9 10, 11, 12, 13]. From the above discussion, it was concluded that the forward speed and vacuum pressure are two major factors that affect the seed spacing uniformity. Therefore, the performance of a pneumatic planter was evaluated taking variable speed and vacuum pressure as factors.

Materials and Methods

Preparation of experimental plot

The experimental plot was selected from the research farm of the Centurion University of Technology and Management, Paralakhemundi Odisha. The plot size was 60×30 m^2area. The plot was irrigated and then ploughed using a mould board plough. The rigid type cultivator was operated on ploughed field to break the large size clod into small pieces. After that, the rotavator was operated to get the well-pulverized soil which help in preparing the raised bed. The headland pattern was followed for tillage and planter operation. The soil moisture content was near about 18% (wb) which is suitable for sowing of seeds. The photographs show the sequence of different operations is shown in Fig. 1.

(a) (b) (c) (d) (e) (f)

Fig. 1: The sequence of the different operations on unploughed land (a) are: ploughing (b), cultivator (c), irrigation (d), rotavator (e) and planting (f) involved in maize cultivation using raised bed pneumatic planter

Test procedure

The two factors i.e. forward speed and vacuum pressure were taken for conducting the experiment. The factors and their levels are shown in Table 1.

Table 1 Factors and their levels for pneumatic planter test

Sl. no.	Name of factors	Levels		
		1	2	3
1	Forward speed, (km/h)	2	3	4
2	Vacuum pressure (kPa)	3	4	5

The two factors forward speed and vacuum pressure have three levels. These levels were set by changing the gears and PTO speeds, respectively. The specifications of the four-row pneumatic planter are given in Table 2.

Table 2 Specification of the four-row pneumatic planter

Particulars	Specifications
Type	Pneumatic type, tractor-mounted PTO shaft driven
Tractor power	50+ hp
Overall dimension	1900×3000×1500 mm
Weight	860 kg
Number of rows	Four
Seed metering	Pneumatic suctioned vertical rotating seed-picking disc
Metering disc	32 holes 4.5 mm diameter
Seed-box capacity	30×4 litter,
Fertilizer metering	Fluted roller
Fertilizer box capacity	130×2 litter
Furrow opener type	Shovel type
Bed dimension	80 cm bottom 60 cm top with adjustable heights
Row spacing	60 cm
Plant spacing	10, 15, 20, 25 cm

The evaluation indexes such as the qualified index, multiple seed index, and missing seed index were evaluated. Respectively, Eq. 1, Eq. 2 and Eq.3 were used to calculate these indexes.

Quality of feed index: $I_q = {n_1}/{N} \dots$ (1)

Multiple seed index: $I_m = {n_2}/{N} \dots$ (2)

Missing seed index: $I_d = {n_3}/{N} \dots$ (3)

Where, n_1 is the number of seed spacing greater than half of the theoretical seed spacing but smaller than 1.5 times; n_2 is the number of seed spacing smaller than half of the theoretical seed spacing; n_3 is the number of seed spacing greater than 1.5 times of theoretical seed spacing; and N isthe total number of seed spacing measured.

Results and Discussion

Effect of forward speed and vacuum pressure on the quality feed index (I_q)

The ANOVA Table 3 reveals that there was no significant effect of forward speed on I_q. However, the ANOVA shows that there was a significant effect of vacuum pressure on I_q at 5% level of significance. It is shown in Fig. 2 that the I_q increases with increasing pressure because at high pressure it grips the seed strongly and drops only after striking with the cut-off device comes after a constant distance. I_q was a maximum of 97.12% at V_F and P_v of 2 km/h and 5 kPa, respectively. I_q was minimum at 91.2% at V_F and P_v of 4 km/h and 3 kPa, respectively.

Table 3 Combined ANOVA for performance parameters of raised bed pneumatic planter tested using two-factor factorial experiment design

Source of variation	dof	*F*-value		
		I_q	I_m	I_d
Model	5	7.9000	93.9800	315.0900
A-Forward speed (C, km/h	1	0.2334	8.5300	789.8100

B-Vacuum pressure, (P_v), kPa	1	39.2200	432.7800	770.7100
A×B	1	0.0042	0.0125	12.5000
A^2	1	0.0247	1.7900	2.0900
B^2	1	0.0050	26.8100	0.3505
Residual	3			
Total	8			

** Denotes highly significant at the 1% level, df: Degrees of freedom, ns: Non-significant.

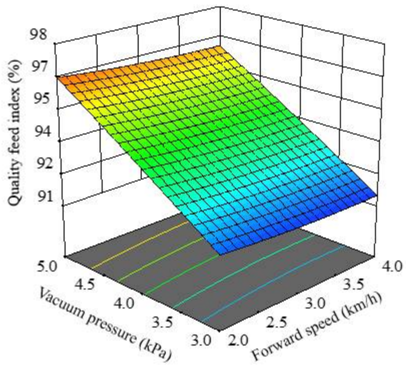

Fig. 2: Response surface showing the effect of forward speed and vacuum pressure on I_q.

Effect of forward speed and vacuum pressure on the multiple seed index (I_m)

The ANOVA Table 3 reveals that there was no significant effect of forward speed on multiple seed index. However, the significant effect of vacuum pressure onmultiple seed index (I_m) at 5% level of significance was reported. This relation is shown in Fig.6 the I_m increases with the vacuum pressure. Probably because at high pressure, the adjacent seeds may pick. I_m was maximum 8.63% at V_F and P_v of 2 km/h and 5 kPa, respectively. I_q was minimum at 2.68% at V_F and P_v of 4 km/h and 3 kPa, respectively.

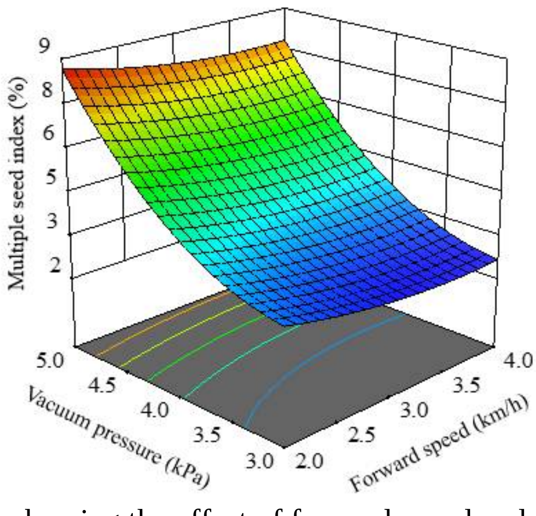

Fig. 3: Response surface showing the effect of forward speed and vacuum pressure on I_m.

Effect of forward speed and vacuum pressure on the missing seed index (I_d).

The ANOVA Table 3 reveals a significant effect on forward speed and vacuum pressure on $I_d$at 5% level of significance. It is shown in Fig.7 that the I_d increases with the increase in forward speed because of getting less time to suck the seed. It possesses inverse relation with the vacuum pressure and was found to be decreased with an increase in pressure because of increasing picking strength. I_d was maximum 5.96% at V_F and P_v of 4 km/h and 5 kPa, respectively. I_q was minimum at 0.96% at V_F and P_v of 2 km/h and 5 kPa, respectively.

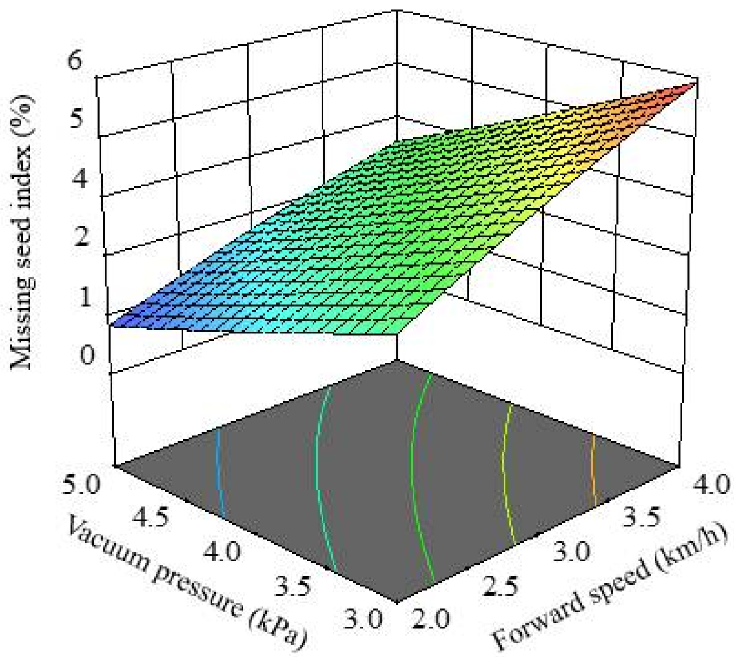

Fig. 4: Response surface showing the effect of forward speed and vacuum pressure on I_d.

The statistical terms such as R^2, Adjusted-R^2, *P*-value, standard deviation, mean, coefficient of variation and adequate precision were also determiend and given in Table 4.

Table 4 R^2, Adjusted-R^2, *P*-value, standard deviation, mean, coefficient of variation and adequate precision for different response variables

Response Variable	R^2	Adjusted R^2	*P* – value	Std. Dev.	Mean	C.V. %	Adequate precision
I_q	0.9294	0.8117	0.0597	0.9296	94	0.989	6.7454
I_m	0.9937	0.9831	0.0017	0.3132	5.16	6.07	23.7231
I_d	0.9981	0.9949	0.0003	0.1075	3.3	3.26	55.8652

Conclusion

On the basis of parameter measurement experience and their analysis, it can be stated that there is negligible variation in seed spacing, seed miss index and seed multiple index. This confirms that the pneumatic planter is a precision planter that has a seed uniformity of more than 97%. Its performance was dependent on the forward speed and vacuum pressure. For the selected maize seed and operating conditions, the forward speed of 3 km/h and vacuum pressure of 4 kPa, give the best results. In these operating conditions, the quality feed index, multiple seed index and missing seed index were 94.41, 4.18 and 3.31%, respectively.

References

1. Anonymous, (2023). Food and Agriculture Organization of the United Nations, Home/FAOSTAT/Data/Production

and Livestock /Country/ India/Crop/ Maize/ Productivity/ Area/ Production /Year. Link: https://www.fao.org/faostat/en/#data/ QCLRome, Italy.

2. Anonymous, (2023). Indian Institute of Maize Research India. Home/About Maize/ Maize Scenario. Link: https://iimr.icar.gov.in/
3. Karayel, D. and Özmerzi, A., (2008). Evaluation of three depth-control components on seed placement accuracy and emergence for a precision planter. *Applied Engineering in Agriculture*, 2**4**(3):271-276.
4. Karayel, D.A.V.U.T., Barut, Z.B. and Özmerzi, A., (2004). Mathematical modelling of vacuum pressure on a precision seeder. *Biosystems Engineering*, **87**(4):437-444.
5. Shafii, S. and Holmes, R.G., (1990). Air-jet seed metering, a theoretical and experimental study. Transactions of the American Society of Agriculture Engineer, 33(5):1-1438.
6. Guarella, P., Pellerano, A. and Pascuzzi, S., (1996). Experimental and theoretical performance of a vacuum seeder nozzle for vegetable seeds. *Journal of Agricultural Engineering Research*, **64**(1):29-36.
7. Abdolahzare, Z. and Mehdizadeh, S.A., 2018. Real time laboratory and field monitoring of the effect of the operational parameters on seed falling speed and trajectory of pneumatic planter. Computers and Electronics in Agriculture, 145:187-198.
8. Quanwei, L., Xiantao, H., Li, Y., Dongxing, Z., Tao, C., Zhe, Q., Bingxin, Y., Mantao, W. and Tianliang, Z., (2017). Effect of travel speed on seed spacing uniformity of corn seed meter. *International Journal of Agricultural and Biological Engineering*, **10**(4):98-106.
9. Yasir, S.H., Liao, Q., Yu, J. and He, D., (2012). Design and test of a pneumatic precision metering device for wheat. Agricultural Engineering International: *International Commission of Agricultural and Bio systems Engineering Journal*, **14**(1):16-25.
10. Singh, R.C., Singh, G. and Saraswat, D.C., (2005). Optimization of design and operational parameters of a pneumatic seed metering device for planting mustard seeds. *International Agricultural Engineering Journal*, **15**(2): 31-41.
11. Ahmad, F., Adeel, M., Qui, B., Ma, J., Shoaib, M., Shakoor, A. and Chandio, F.A., (2021). Sowing uniformity of bed-type pneumatic maize planter at various seedbed preparation levels and machine travel speeds. *International Journal of Agricultural and Biological Engineering*, **14**(1):165-171.
12. Dixit A., Mahal J.S., Manes G.S., Khurana R, Nare B. (2011). Comparative performance of tractor-operated inclined plate and pneumatic Planters. *Agricultural Engineering Today*, **35**(1):33-7.
13. Jinqing, L., Ying, Y., Zihui, L., Qinqin, S., Jicheng, L. and Zhongyuan, L., (2016). Design and experiment of an air-suction potato seed metering device. *International Journal of Agricultural and Biological Engineering*, **9**(5):33-42.