Indices for Comparative Performance Evaluation of Seed Drills

by
N. S. Chandel*
Scientist
ICAR - Central Institute of Agricultural Engineering,
Nabi-bagh, Berasia Road, Bhopal,
Madhya Pradesh - 462 038, INDIA
*Corresponding author: narendracae@gmail.com

Dilip Jat
Scientist
ICAR - Central Institute of Agricultural Engineering,
Nabi-bagh, Berasia Road, Bhopal,
Madhya Pradesh - 462 038, INDIA

C. R. Mehta
Director
ICAR - Central Institute of Agricultural Engineering,
Nabi-bagh, Berasia Road, Bhopal,
Madhya Pradesh - 462 038, INDIA

Y. A. Rajwade
Scientist
ICAR - Central Institute of Agricultural Engineering,
Nabi-bagh, Berasia Road, Bhopal,
Madhya Pradesh - 462 038, INDIA

Abstract

The performance of a seed drill depends on manufacturing quality, precision and performance under field condition. In this study, an overall performance index was developed to compare performance of seed drills manufactured in different regions of Madhya Pradesh state of India for sowing of soybean and wheat crops. The test parameters of seed drills such as inter row variation of seed and fertilizer, seed damage, variation in seed placement, number of seeds dropped per meter, effective field capacity, field efficiency, fuel consumption, working width, type of furrow opener, hardness of furrow opener and weight of machine were selected to calculate precision, performance, machine quality and overall performance indices of seed drills. A completely randomized design was used to analyze test data of selected 90 seed drills. The average precision index of seed drills was 0.70 and 0.64 for wheat and soybean crops, respectively. The average performance index of seed drills was 0.72 and 0.73 for sowing of wheat and soybean crops, respectively. The machine quality index of the seed drills varied from 0.60 to 0.72. The overall performance index of the seed drills was 0.70 for wheat and 0.67 for soybean crops. The overall performance of seed drills manufactured in *Malwa* plateau of Madhya Pradesh was the best for sowing of wheat (0.74) and soybean (0.72) crops. Significant difference was observed among the seed drills manufactured in different regions of Madhya Pradesh based on precision, performance, machine quality and overall performance indices.

Keywords: Agro-climatic regions, performance index, precision index, machine quality, seed drill.

Introduction

Agriculture remains as principal means of livelihood for over 58% of the rural households. Over the year, number of people engaged in agricultural activities have decreased to 54% in 2011, which are further expected to go down to 40% in 2020 and 26% in 2050 (Mehta et al., 2018). This decline is accompanied by increase in daily wage rates from INR 87 in 2008-09 to INR 214 in 2012-13. Food grain productivity in India has increased from 522 kg/ha in 1950-51 to 2042 kg/ha in 2015-16 (Anonymous, 2017a). However, food grain production needs to be increased by about 40% by 2050 from 275 MT in 2017-18 to achieve food security to meet demand of growing population. The farm power availability has increased from 0.30 kW/ha in 1960-61 to 1.92 kW/ha in 2016-17. The overall mechanization level on Indian farms varies from 45 to 50% for different crops, as compared to 90% in developed countries (Mehta et al., 2014).

The availability of tractors has increased from one in 150 ha to one in 30 ha (Senthilkumar et al., 2017). However, similar growth rate was not reported for other farm machin-

ery such as threshers, rotavators and power tillers (Anonymous, 2017b). Among different field operations, tillage and threshing are highly mechanized whereas sowing/planting is the least mechanized in India (Singh, 2015). More than 5000 farm machinery manufacturers produce 315,000-400,000 units of tillage and 63,500-79,000 units of threshing machineries every year in India. However, only around 2,500 farm machinery manufacturers are manufacturing 75,000?100,000 units of seeding/planting equipment (Singh, 2016). The number of manufacturers of sowing and planting machineries are low due to poor quality of manufacturing facilities, low workmanship, and small market as compared to other agricultural machineries. If manufacturing standards and quality norms are followed then the field performance of machinery will be enhanced (Mehta et al., 2014). The Food and Agriculture Division of BIS ensures manufacturing of agricultural products/equipment and their quality through its network of testing centres and laboratories through specific test codes. In addition, the government of India has also set up farm machinery testing centres to ensure manufacturing of quality farm machinery. The quality of farm equipment is ensured through performance evaluation under laboratory and field conditions at different farm machinery testing institutes and designated test centres (Anonymous, 2011).

The manufacturing of agricultural machinery in India is quite multifaceted and comprises of village artisans, tiny units, small-scale industries, State Agro-industrial Development Corporations and multinational companies. The quality of farm equipment manufactured at small scale industries is poor due to improper design, poor manufacturing facilities, and use of substandard and low quality materials (NAAS, 2016). Most of the farm machinery are not manufactured as per relevant BIS standards and their performance also do not conform the standards. However, there is still scope to improve the quality of agricultural implements, manufactured by small-scale manufacturers (Singh, 2015). It is necessary for a farm machinery to meet requirements of minimum performance standards (MPS) during testing of machinery. Singh et al. (2005) optimized design and operational parameters of pneumatic metering mechanism for cotton seed based on the miss index, multiple index, quality feed index and precision in spacing under laboratory and field conditions. Maleki et al. (2006) introduced a new index named coefficient of uniformity which was less sensitive for data outliers as compared to coefficient of variation for assessment of seed uniformity for seed drills.

The right selection of the agricultural machinery is a prerequisite for proper functioning for intended farm operation for sustainable agriculture (Cupiał et al., 2015). It will help in increase in productivity by 30% and reduce input costs by 20% (FICCI, 2015). The performance of tillage, sowing, and harvesting machinery is evaluated based on effective field capacity, field efficiency, fuel consumption, labour requirement, cost of operation etc. Among the tillage equipment, the performance index for moldboard plough is based on overall performance at a particular soil condition. It will also depend on the depth of operation, effective field capacity, soil inversion, pulverization, and draft requirement (BIS, 1999). Similarly, overall performance index developed by Behera et al. (1995) for seed

Table 1 Agro-climatic region wise details of major crops grown, soil type and rainfall pattern of Madhya Pradesh

Sl. No.	Agro-climatic region	Major crops grown	Soil type	Rainfall, mm	Ftab 5%	Ftab 1%
1	Gird Region	Wheat, soybean, Jowar	Alluvial (Light)	800-1000	891	3555
2	Bundelkhand	Wheat, soybean, Jowar	Mixed red and black (Medium)	800-1400	895	2611
3	Satpura Plateau	Wheat, soybean, Jowar	Shallow black (Medium)	1000-1200	995	2569
4	Nimar Plains	Wheat, soybean, cotton	Medium black (Medium)	800-1000	946	3148
5	Jhabua Hills	Wheat, soybean, cotton	Medium black skeletal (Light/Medium)	800-1000	977	2760
6	Kymore Plateau and Satpura hills	Rice, wheat, soybean	Mixed red and black soils (Medium)	1000-1400	901	2227
7	Vindhya Plateau	Wheat, soybean, rice	Medium black and deep black (Medium/Heavy)	1200-1400	959	2622
8	Central Narmada Valley	Wheat, soybean,	Deep black (deep)	1200-1600	925	3595
9	Malwa Plateau	Wheat, soybean, cotton	Medium black (Medium)	800-1200	1025	3309
10	Chhattisgarh plains	Rice	Red and yellow (Medium)	1200-1600	834	1331
11	Northern Hill Region of Chhattisgarh	Rice, wheat	Red and yellow medium black and skeltal (Medium/light)	1200-1600	632	1820

Source: http://www.mp.gov.in/en/web/guest/mp-krishi/arg-st/landuse-ir-pop/argo-climatic (accessed on 16/06/2018)
http://mpkrishi.mp.gov.in/Compendium/APY1_12_05_2017.xls (accessed on 16/06/2018)

drills was based on their evaluation under field condition only. In addition, precision index is based on direct impact on quality and field performances of agricultural machinery. Precision index proposed by NAAS (2016) covered different attributes of seed drills such as inter row variation of seed and fertilizer, seed damage and seeding depth for seed cum fertilizer drill.

Thus, the majority of indices developed for comparative evaluation of seed drills were based on the performance of metering mechanism or furrow opener of the seed drills under laboratory and field conditions. However, few studies have been carried out for assessment of manufacturing quality of equipment and their impact on performance and precision. The study focuses on development of an overall performance index of seed drills based on precision, performance and manufacturing quality indices of the machinery to help in selection of better quality machinery by farmers.

Material and Methods

Selection of Seed Drills

There are 11 agro-climatic regions in Madhya Pradesh (MP) state of India (**Table 1**). The region-wise details of major crops grown, soil type, rainfall and productivity of soybean and wheat crops are reported in **Table 1**. The seed drills with fluted roller type metering mechanism having shoe or shovel type furrow opener are commonly manufactured in Madhya Pradesh state of India and are used for sowing of wheat, soybean, gram, lentil and maize crops.

Ten number of seed drills were selected from each of nine agro-climatic regions of Madhya Pradesh state except Chhattisgarh plains and Northern hill region of Chhattisgarh. Test data of 90 seed drills tested at Farm Machinery Testing Centre of ICAR-Central Institute of Agricultural Engineering, Bhopal in Madhya Pradesh state of India were compiled for the study. The general specifications of selected seed drills tested at the centre for soybean (cv. JS 9305) and wheat (cv. HI 1544) seeds are given in **Table 2**. The selected seed drills are having category II type three point hitch meeting the requirements of IS 4468, part1 (BIS, 1997). The parameters of seed drills such as inter row variation of seed and fertilizer, seed damage, variation in seed placement depth, number of seeds per meter row length, field capacity, field efficiency, fuel consumption, working width, type of furrow opener, hardness of furrow opener, conformity of hitching with BIS and weight of machine were taken for development of precision, performance and machine quality indices.

Development of Indices

Indices were developed to assess the precision, performance and manufacturing quality of seed drill using 13 parameters. To assign the rating, parameters were arranged in order depending on whether a higher value was considered 'good' or 'bad' in terms of machine quality, performance and precision. A weight to each parameter was as-

Table 2 General specifications of seed drills manufactured in Madhya Pradesh

Components	Constructional details	Material	Specifications
Overall dimensions	Length, mm Width, mm Height, mm	- - -	1800-2800 1300-1700 1200-1550
Weight of machine	Seed drill Seed-cum-fertilizer drill	-	371±50 kg 406±65 kg
Frame	Square box, C-Channel, square box Channel	Mild steel	Adjustable row spacing
Tyne	7/9/11/13 Nos	Mild steel	Straight/ curved
Furrow opener	Shoe or shovel	High carbon steel	Hardness, HB Shoe type: 230±46 Shovel type: 286±75
Metering mechanism	Fluted roller	Cast iron, Aluminium, plastic	Cup type with 7-10 flutes
Hopper	Trapezoidal shape	Galvanised iron sheet	Capacity: 100-150 kg Sheet thickness: 1.5-2.0 mm
Hitch	Three point hitch	Mild steel	Category II
Seed and Fertilizer tubes	Transparent, flexible	Plastic tubes	25-30 mm diameter
Ground wheel	Front or rear mounted (lug type)	Mild steel	Diameter, m Front: 0.40±0.03 Rear: 0.75±0.05
Power transmission system	Chain and sprocket	Carbon and alloy steel Mild steel	2 Nos for chain 4 Nos for sprocket

signed based on its contribution in achieving the higher precision, performance and better quality of machine. The recommended range, rating and weightage assigned to different parameters for calculation of different indices are given in **Table 3**. The values were transformed using a linear scoring technique (Andrews et al., 2002). The indices for comparative evaluation of seed drills were developed on the basis of weightage and rating assigned to the selected parameters.

The range for different parameters for precision index i.e. inter-row variation of seed (0-7.5%), inter-row variation of fertilizer (0-12%) and seed damage (0-0.5%) were selected as per recommendation of IS 6813 (BIS, 2000). Their ratings were selected based on recommendations of NAAS (2016). Each parameter was given a rating depending on their importance within the recommended range. Precision in sowing depends on inter-row variation of seed and fertilizer, seed damage, variation in seed placement depth and number of seeds per meter row length (NAAS, 2016). These attributes were selected for calculation of precision index.

Effective field capacity, field efficiency, fuel consumption and working width of seed drills were considered for calculation of the performance index. The ratings of different parameters for calculation of performance index were taken from Senapati et al. (1992).

The manufacturing quality of seed drills is an important parameter for proper functionality of the machine. The type of furrow opener, hardness of furrow opener, conformity of hitching pyramid with BIS and weight of machine were selected for calculation of manufacturing quality index. The recommended range for hardness of cutting edge of furrow opener of seed drills is 350- 450 HB (BIS, 1983). Therefore, higher rating of 1 was assigned for hardness more than 350 HB and lower value of 0.6 for hardness less than 250 HB. The dimensions of hitching system of seed drill (12 parameters) should be as per IS 4468, part1 (BIS, 1997). The machine that con-

Table 3 Rating and weightage assigned to different parameters of seed drills for calculation of precision, performance and machine quality indices

Parameters	Recommended values	Range	Rating (R)	Weightage (W)
Precision Index				
Inter row variation of seed, %	0-7	≤1.00	1.0	0.3
		1.01-3.00	0.8	
		3.01-5.00	0.6	
		5.01-7.00	0.4	
		≥7.01	0.2	
Inter row variation of fertilizer, %	0-12.5	0-2.50	1.0	0.2
		2.51-5.00	0.9	
		5.01-7.50	0.8	
		7.51-10.00	0.7	
		10.01-12.00	0.6	
		≥12.01	0.5	
Seed damage, %	0-0.5	0-0.25	1.0	0.1
		0.26-0.50	0.8	
		>0.5	0.6	
Variation in seed placement depth, %	0-20	0-5.0	1.0	0.1
		5.1-10.0	0.8	
		10.1-15.0	0.6	
		15.1-20.0	0.4	
		>20.0	0.2	
Seeds per meter row length, no	25-40 (Wheat) 18-27 (Soybean)	>40 >27	1.0	0.3
		36-40 25-27	0.9	
		31-35 22-24	0.8	
		26-30 19-21	0.7	
		≤25 ≤18	0.6	

Parameters	Recommended values	Range	Rating (R)	Weightage (W)
Performance Index				
Effective field capacity, ha/h	0.4-0.8	>0.80	1.0	0.3
		0.71-0.80	0.9	
		0.61-0.70	0.8	
		0.51-0.60	0.7	
		≤0.5	0.6	
Field efficiency, %	70-90	>90.0	1.0	0.3
		80.1-90	0.9	
		70.1-80.0	0.8	
		≤70.0	0.7	
Fuel consumption, l/h	1.5-3.5	≤1.5	1.0	0.3
		1.6-2.5	0.8	
		2.6-3.5	0.6	
		>3.5	0.4	
Working width, m	1.5-3.0	>2.25	1.0	0.1
		2.01-2.25	0.9	
		1.76-2.00	0.8	
		1.51-1.75	0.7	
		≤1.50	0.6	
Machine Quality Index				
Hardness of furrow opener, HB	350-450	>350	1.0	0.3
		251-350	0.8	
		≤250	0.6	
Hitching pyramid	12	12	1.0	0.2
		9-11	0.9	
		6-8	0.8	
		3-5	0.7	
		<3	0.6	
Weight of machine, kg	300-400	>400	1.0	0.2
		350-400	0.9	

forms all 12 parameters for hitching was assigned the highest rating of 1 and lower value of 0.7 was assigned which conform to less than 4 parameters. The shoe type furrow opener performs better than shovel type of furrow opener. Therefore, rating values of 1 and 0.8 are assigned to shoe and shovel type furrow openers, respectively (Damora and Pandey, 1995; Chaudhuri, 2001).

The precision, performance and machine quality indices were determined by following equation (Senapati et al., 1992; Afzalinia et al., 2006):

$$I = \sum_{i=1}^{n} R_i W_i$$

Where,

I = Precision or performance or machine quality index

R_i = Rating of i^{th} parameter considered for corresponding index

W_i = Fractional weightage of i^{th} parameter considered for the index

n = Number of parameters considered for the index

An overall performance index was calculated by considering precision, performance and manufacturing quality indices. Overall performance index (OPI) was calculated by assigning weightage of 0.4, 0.3 and 0.3 for precision, performance and machine quality indices, respectively.

$$OPI = \sum_{i=1}^{n} I_i W_i$$

Where,

OPI = Overall performance index,

I_i = Value of each index,

W_i = Fractional weighting of each index, and

n = Number of indices.

Statistical Analysis of Data

The analysis of test data of 90 seed drills was done by SPSS statistical program (v.10) and values were arranged according to Duncan's multiple range test. The means at 5% level of significance ($P < 0.05$) was calculated to test the significance of differences between parameters.

Results and Discussion

Precision Parameters

The results of ANOVA of different parameters selected for development of precision index of the selected seed drills are given in **Table 4**.

Seed Placement Depth

There was no significant difference in seed placement depth for wheat and soybean seeds among seed drills of different regions. The variation in seed placement depth for wheat and soybean seeds varied from 1.87 to 5.08% and 5.38 to 23.46%, respectively (**Table 4**). The higher variation in seed placement depth in soybean was due to more depth of seed bed prepared after summer ploughing and followed by sowing under high soil moisture content during rainy season. Seed placement depth also depends on the type of furrow opener. It was observed that the shoe type furrow opener performed better as compared to the shovel type furrow opener in vertisol.

Inter Row Variation in Seed

There was significant difference ($p < 0.0001$) in inter row variation in seed placement for wheat and soybean seeds by the selected seed drills. The maximum variation in inter row placement of seeds was found in seed drills of Vindhya Plateau (6.50%) and followed by Bundelkhand (6.11%), Jhabua Hills

Table 4 ANOVA of different parameters used for precision index

Agroclimatic regions	Wheat					Soybean				
	Variation in seed placement depth, %	Inter row variation in seed, %	Inter row variation in fertilizer, %	Seed damage, %	Number of seeds per meter, No.	Variation in seed placement depth, %	Inter row variation in seed, %	Inter row variation in fertilizer, %	Seed damage, %	Number of seeds per meter, No.
Gird	4.17	5.76^{AB}	8.07^{A}	0.32^{C}	30	6.37	5.49^{ABC}	8.26^{A}	0.41	26
Bundelkhand	3.33	6.11^{AB}	6.10^{AB}	0.33^{BC}	30	5.38	4.12^{CD}	6.40^{AB}	0.39	22
Satpura Plateau	2.50	5.25^{ABC}	7.96^{A}	0.49^{A}	30	10.42	5.18^{ABC}	7.80^{AB}	0.49	22
Nimar Valley	5.08	5.02^{BC}	6.09^{AB}	0.44^{AB}	30	14.85	4.25^{C}	6.01^{AB}	0.50	25
Jhabua Hills	1.87	5.92^{AB}	5.67^{AB}	0.39^{ABC}	32	18.04	4.47^{BC}	5.33^{B}	0.46	25
Kymore Plateau & Satpura Hills	8.33	5.90^{AB}	7.21^{AB}	0.45^{ABC}	35	23.46	5.95^{A}	7.93^{AB}	0.49	23
Vindhya Plateau	2.08	6.50^{A}	7.23^{AB}	0.43^{ABC}	24	7.83	5.71^{AB}	8.28^{A}	0.51	21
Central Narmada Valley	7.71	4.40^{CD}	7.20^{AB}	0.36^{ABC}	32	21.04	5.15^{ABC}	8.43^{A}	0.43	23
Malwa Plateau	4.51	3.75^{D}	5.71^{B}	0.37^{BC}	30	10.88	2.94^{D}	5.56^{B}	0.44	20
Mean	4.45	5.14	6.60	0.40	30	12.91	4.50	6.82	0.46	23
p-value	0.2245	<.0001	0.0345	0.0160	0.0682	0.2146	<.0001	0.0041	0.1796	0.3379
CV (%)	75.45	11.55	17.19	15.22	11.9	73.25	14.26	18.59	13.52	17.2
	NS	**	*	*	NS	NS	**	**	NS	NS

*** Significant at 1% (P < 0.01), * Significant at 5% (P < 0.05), NS - Non Significant*

A, B, C and D - Means within a column followed by the same letters are not significantly different.

(5.92%), Gird (5.76%), Kymore Plateau & Satpura hills (5.90%) and Satpura Plateau (5.25%) regions of Madhya Pradesh. The inter row variation in placement of seeds by the seed drills manufactured in different regions of Madhya Pradesh was within the recommended limit of less than 7% (IS 6813, 2000). Among the different agro-climatic regions, seed drills manufactured in Malwa plateau had the lowest inter row variation in placement of wheat (3.75%) and soybean (2.94%) seeds.

Inter Row Variation in Fertilizer

There was a significant difference in inter row variation in fertilizer placement by the seed drills manufactured in different agro-climatic regions for wheat and soybean crops (**Table 4**). It varied from 5.7 to 8.07% and from 5.56 to 8.43% for wheat and soybean crops, respectively. The inter row variation in fertilizer placement was due to seasonal variability and seed bed conditions during sowing of wheat and soybean seeds. Hygroscopic nature of fertilizer also increased the variability. The variability was also due to different sizes of flute diameter used in the seed drills manufactured in different regions. The inter row variation in fertilizer placement for the selected seed drills from different regions was within IS 6813 recommended limit of less than 12.5% (BIS, 2000).

Seed Damage

It was observed that there was significant difference ($p < 0.05$) in seed damage for wheat seeds and no significant difference for soybean seeds for seed drills manufactured in different regions of Madhya Pradesh. Seed damage varied from 0.32% (Gird) to 0.49% (Satpura plateau) for wheat seeds and from 0.39% (Bundelkhand) to 0.51% (Vindhya Plateau) for soybean seeds. The seed damage was more in soybean as compared to wheat seeds. This might be due to difference in seed size, moisture content, and breakage of soybean seed coat during drilling.

Number of Seeds per Meter

There was no significant difference in number of seeds dropped per meter length for wheat as well as soybean crops by seed drills manufactured in different agro-climatic regions. The average number of seeds dropped per meter for wheat and soybean seeds were 30 and 23, respectively.

Performance Parameters

The results of statistical analysis of different variables considered for development of performance index of seed drills of different agro-climatic regions of Madhya Pradesh are given in **Table 5**.

Width of Operation

For wheat crop, there was no significant difference in width of operation for sowing of seeds by seed drills manufactured in different agro-climatic regions. The average width of operation of seed drills was 2.18 m. The seed drills manufactured in Vindhya plateau had the maximum (2.63 m) width of operation and Jhabua Hills and Bundelkhand regions had minimum (2.03 m) width of operation. In Madhya Pradesh, the wheat seeds are commonly sown in close row to row spacing. Farmers of the region do not follow weeding or intercultural operations after sow-

Table 5 ANOVA of different parameters used for performance index

Agroclimatic regions	Wheat				Soybean			
	Width of operation, m	Effective field capacity, ha/h	Field efficiency, %	Fuel consumption, l/h	Width of operation, m	Effective field capacity, ha/h	Field efficiency, %	Fuel consumption, l/h
Gird	2.18	0.49^{H}	69.44^{CD}	3.13	1.58^{AB}	0.53^{AB}	67.40^{CD}	4.40
Bundelkhand	2.03	0.55^{G}	74.87^{ABC}	3.54	1.58^{AB}	0.46^{B}	68.30^{BC}	4.61
Satpura Plateau	2.18	0.57^{FG}	67.31^{D}	3.58	1.58^{AB}	0.59^{AB}	63.93^{D}	4.62
Nimar Valley	2.12	0.64^{CD}	79.70^{A}	3.63	1.53^{ABC}	0.53^{AB}	71.59^{AB}	4.62
Jhabua Hills	2.03	0.61^{DE}	72.45^{BCD}	3.58	1.30^{C}	0.61^{AB}	70.85^{ABC}	4.24
Kymore Plateau & Satpura Hills	2.18	0.60^{EF}	74.98^{ABC}	3.64	1.50^{BC}	0.50^{AB}	69.25^{ABC}	4.34
Vindhya Plateau	2.63	0.67^{BC}	75.54^{ABC}	3.52	1.73^{A}	0.68^{A}	69.83^{ABC}	4.74
Central Narmada Valley	2.33	0.69^{AB}	72.62^{BCD}	3.85	1.58^{AB}	0.58^{AB}	68.70^{ABC}	5.07
Malwa Plateau	2.14	0.71^{A}	75.52^{AB}	3.73	1.58^{AB}	0.65^{A}	71.79A	4.50
General mean	2.18	0.63	74.24	3.60	1.55	0.58	69.62	4.56
p-value	0.15	<0.0001	0.0001	0.5033	0.0018	0.0300	<.0001	0.4959
CV (%)	11.39	2.72	3.63	10.30	6.00	15.00	2.44	9.69
	NS	**	**	NS	**	*	**	NS

*** Significant at 1% (P < 0.01), * Significant at 5% (P < 0.05), NS - Non Significant*
A, B, C, D, E, F, G and H - Means within a column followed by the same letters are not significantly different

ing. Therefore, sowing of wheat in 9 to 11 rows by the seed drill is the most common practice for utilizing the maximum width of operation of machine. The width of operation of seed drills varied significantly ($p < 0.05$) across agro-climatic regions for sowing soybean crop. The seed drills manufactured in Jhabua hill region had the lowest (1.30 m) width of operation and in Vindhya plateau had the highest (1.73 m) with an average value of 1.55 m across the regions. This might be due to the variation in soybean cultivation practices (flat bed, ridge furrow and raised bed) among different agro-climatic regions leading to different width of operation. Lowest width of operation in the Jhabua hill region may be due to small size and irregular shape of hilly and stony fields. In this hilly region, there is a scope for utilizing high capacity machinery for timeliness of farm operations.

Effective Field Capacity

The effective field capacity of seed drills manufactured in different agro-climatic regions varied significantly for sowing of wheat as well as soybean crops. The seed drills manufactured in MP had an average effective field capacity of 0.63 ha/h for wheat and 0.58 ha/h for soybean crops. The effective field capacity of seed drills was maximum of 0.71 ha/h for wheat and 0.65 ha/h for soybean crops for machineries manufactured in Malwa plateau. However, it was minimum of 0.46 ha/h for soybean crop in Bundelkhand region and 0.49 ha/h for wheat crop in Gird region.

Field Efficiency

The field efficiency of machineries manufactured in different agro-climatic regions varied significantly ($p < 0.05$) for sowing of wheat as well as soybean crops. The average field efficiency of the seed drills was 74 and 70% for wheat and soybean crops, respectively. The maximum field efficiency of 80% was observed for sowing of wheat crop for machineries manufactured in Nimar valley whereas minimum of 67% was in Satpura plateau.

Fuel Consumption

There was no significant difference in fuel consumption of machineries manufactured across different agro-climatic regions for sowing of wheat as well as soybean crops. However, an average fuel consumption of tractor operated seed drills was 3.6 l/h for wheat crop as compared to 4.56 l/h for soybean crop. The fuel consumption was higher for sowing of soybean seeds due to difficulty in sowing during rainy season.

Table 6 ANOVA of different parameters used for machine quality index

Agro-climatic regions	Hardness, HB	Weight of machine, kg	Hitch pyramid, No.
Gird	251^{ABC}	383^{AB}	6
Bundelkhand	242^{ABC}	368^{AB}	5
Satpura Plateau	231^{BC}	375^{AB}	6
Nimar Valley	297^{AB}	325^{B}	5
Jhabua Hills	295^{ABC}	355^{AB}	6
Kymore Plateau & Satpura Hills	205^{C}	318^{B}	6
Vindhya Plateau	323^{A}	388^{AB}	5
Central Narmada Valley	225^{BC}	403^{A}	5
Malwa Plateau	289^{AB}	401^{A}	5
General mean	268	371	6
p-value	0.009	0.019	0.776
CV (%)	14.9	9.9	21.7
	**	*	NS

*** Significant at 1% (P < 0.01), * Significant at 5% (P < 0.05), NS - Non Significant*
A, B and C - Means within a column followed by the same letters are not significantly different.

Manufacturing Quality Parameters

The results of ANOVA of different parameters selected for development of manufacturing quality index of seed drills are given in **Table 6**.

Hardness of Furrow Opener

There was significant difference in the hardness of furrow openers of seed drills manufactured in different agro-climatic regions of Madhya Pradesh (**Table 6**). The higher value of hardness was observed for machineries manufactured in Vindhya plateau (323 HB) and followed in Nimar Valley (297 HB). These regions have medium black soils which lead to more wear in working component of agricultural machinery. In addition, better manufacturing facilities, availability of quality materials and competitiveness among manufacturers in these regions aid in fabrication of better quality of machinery. However, the lowest hardness of furrow opener of 205 HB was observed in machineries of Kymore Plateau and Satpura hills regions. The hardness of soil working component also varied based on type of furrow opener. Among the tested machines, 67% of seed drills had shovel type furrow opener (**Table 1**). The hardness of shoe type of furrow opener was higher (286 ±75 HB) as compared to shovel type (230 ±46 HB) furrow opener (**Table 1**). Overall, hardness of 38.5% furrow openers conformed to IS 10691 (BIS, 1983).

Machine Weight

The weight of seed drills varied significantly ($p < 0.05$) among different agro-climatic regions. It varied from 305 to 515 kg with an average value of 371 kg (**Table 6**). The average weight of seed drills was the highest (403 kg) for machineries manufactured in Central Narmada

Valley and the lowest weight of 318 kg in Kymore Plateau & Satpura hills region. The variation in weight of seed drills was recorded due to type of seed drill, number of tynes and frame section. The weight of seed drills manufactured in Central Narmada Valley and Malwa plateau regions was higher as compared to machinery manufactured in other regions due to sale of seed-cum-fertilizer drills in the regions. The average weight of seed-cum-fertilizer drills was higher (406 ±65 kg) as compared to that of seed drills (371 ±50 kg) manufactured in Madhya Pradesh. The weight of seed drills was also higher due to more numbers of furrow openers (11 or 13) used in the seed drills of Central Narmada Valley and Malwa Plateau regions. The average weight of seed drills manufactured in Madhya Pradesh state increased from 366 ±44 kg to 473 ±25 kg with increase in number of tynes from 9 to 13. The variation in the weight of machine was also due to type of frame section of seed drill. The average machine weight for frame sections of square box, C-channel and square box channel was 387, 393 and 420 kg, respectively.

Hitch Pyramid

The seed drills manufactured in different agro-climatic regions had no significant difference in hitch pyramid. Among 12 parameters of hitch pyramid, an average of 6 parameters of the selected seed drills conform to IS 4468, part1 (BIS, 1997). However, all the seed drills conform to two parameters of hitch pyramid viz., diameter of lower and upper linch pin hole (12 mm).

Indices for Seed Drills

The calculated values of precision, performance, machine quality and overall performance indices of the seed drills of different agro-climatic regions of Madhya Pradesh are reported in **Table 7**.

Precision Index

There was significant difference in precision indices of seed drills manufactured in different agro-climatic regions for both the crops. The precision index of the seed drills varied from 0.59 to 0.74 for sowing of wheat and soybean seeds with an average values of 0.70 and 0.64 for wheat and soybean crops, respectively (**Table 7**). The precision indices of seed drills manufactured in Vindhya plateau and Malwa plateau regions were the highest for sowing of wheat and soybean seeds, respectively due to less variation in seed placement, inter-row variations in seed and fertilizer and seed damage. The parameters affecting precision index mainly depend on types of metering mechanism and furrow opener. The higher precision index of seed drills manufactured in Malwa Plateau for soybean seeds was mainly due to use of shoe type of furrow opener. Chaudhuri (2001) also reported that the shoe type furrow opener performed better in black soil and had less lateral and vertical variations of seed and fertilizer placement as compared to other types of furrow openers. The seed drills selected for the study have fluted roller type metering mechanism. The flute diameter of seed drills manufactured in Malwa plateau was more as compared to those manufactured in Vindhya plateau region. Therefore, the precision indices of the seed drills of Malwa plateau and Vindhya plateau regions were higher for sowing of soybean and wheat crops, respectively. The ground wheel size and position are other important parameters that influenced the precision of seed drills. Among the selected

Table 7 Precision, performance, machine quality and overall performance indices of seed drill manufactured in different agro-climatic regions of Madhya Pradesh

Agroclimatic regions	Precision Index		Performance Index		Machine Quality Index	Overall Performance Index	
	Wheat	Soybean	Wheat	Soybean		Wheat	Soybean
Gird	0.67^{BC}	0.60^{B}	0.69^{AB}	0.73^{AB}	0.64^{BC}	0.67^{BC}	0.65^{CD}
Bundelkhand	0.71^{AB}	0.59^{B}	0.71^{A}	0.77^{A}	0.61^{C}	0.68^{BC}	0.65^{CD}
Satpura Plateau	0.63^{C}	0.62^{B}	0.70^{AB}	0.66^{AB}	0.60^{C}	0.64^{C}	0.63^{D}
Nimar Valley	0.71^{AB}	0.62^{B}	0.74^{A}	0.76^{A}	0.68^{ABC}	0.71^{AB}	0.68^{BC}
Jhabua Hills	0.67^{BC}	0.65^{AB}	0.74^{A}	0.76^{AB}	0.71^{AB}	0.70^{AB}	0.70^{AB}
Kymore Plateau & Satpura Hills	0.70^{ABC}	0.60^{B}	0.71^{A}	0.64^{B}	0.60^{C}	0.67^{BC}	0.61^{D}
Vindhya Plateau	0.74^{A}	0.69^{A}	0.61^{B}	0.68^{AB}	0.69^{ABC}	0.68^{BC}	0.69^{ABC}
Central Narmada Valley	0.73^{AB}	0.65^{AB}	0.75^{A}	0.70^{AB}	0.63^{BC}	0.70^{AB}	0.66^{BCD}
Malwa Plateau	0.73^{A}	0.70^{A}	0.77^{A}	0.76^{A}	0.72^{A}	0.74^{A}	0.72^{A}
General mean	0.70	0.64	0.72	0.73	0.66	0.70	0.67
p-value	0.0014	0.0229	0.0008	0.0001	0.0003	0.0001	<.0001
CV (%)	4.27	4.85	5.84	7.70	5.92	3.29	3.27

*** Significant at 1% (P < 0.01), * Significant at 5% (P < 0.05), NS - Non Significant*
A, B, C and D - Means within a column followed by the same letters are not significantly different.

seed drills, 79% had front mounted ground wheel. The front mounted ground wheel resulted in better maneuverability and ease of operation. However, machines manufactured in Malwa plateau region have ground wheel mounted at the rear side. The average diameter of rear mounted ground wheel was higher (0.75 ±0.05 m) as compared to front mounted ground wheel (0.40 ±0.03 m) (**Table 1**). The higher diameter of wheel minimized skid of ground wheel and thus maintained uniform seed rate and resulted in higher precision.

Performance Index

The performance index of a machinery mainly depends on effective field capacity and field efficiency of the machine. The performance indices of seed drills for sowing of wheat and soybean seeds were significantly influenced by machinery manufactured in different agro-climatic regions. The average performance index of 0.72 and 0.73 was observed for sowing of wheat and soybean seeds, respectively (Table 7). Machineries manufactured in Malwa plateau and Bundelkhand region had the highest (0.77) performance index for wheat and soybean seeds, respectively. The lowest performance index was recorded for machineries manufactured in Vindhya plateau for sowing of wheat (0.61) and in Kymore plateau and Satpura hills region for soybean (0.64) seeds. These performance parameters were higher for seed drills manufactured in Malwa plateau. In addition, better maneuverability, ease of operation, no breakdown during operation and less number of turns aided in higher performance index. The seed drills of this region also had large size of seed box that avoided frequent refilling.

Machine Quality Index

Among the different agro-climatic regions, the machine quality indices were significantly higher for machinery manufactured in Malwa plateau (0.72) and followed in Jhabua hills (0.71) and Vindhya plateau (0.69) (**Table 7**). The machine quality index was found lower (0.60) in Satpura plateau and Kymore plateau & Satpura hills. The machine quality parameters i.e. hardness of furrow opener and weight of machine were higher in Malwa plateau, Jhabua hills and Vindhya plateau as compared to other regions of Madhya Pradesh. The major farm machinery manufacturing clusters are located at Indore (Malwa plateau) and Bhopal (Vindhya plateau) in Madhya Pradesh state. This may be due to better infrastructure, manufacturing facilities and availability of skilled man power in these regions. The farmer's awareness towards mechanization and higher sale volume of agricultural machinery in these regions also created competitiveness among manufacturers for maintaining quality of machinery. The variation in manufacturing quality of seed drills manufactured by different manufactures was also reported by NAAS (2016). It was due to variation in design, manufacturing processes involved, materials of construction and lack of standardization of various components of the equipment.

Overall Performance Index

The overall performance index of seed drills manufactured in Madhya Pradesh varied significantly among different agro-climatic regions. The overall performance index varied from 0.64 to 0.74 with an average value of 0.70 for wheat and from 0.61 to 0.72 with an average value of 0.67 for soybean seeds (**Table 7**). The findings of the study are consistent with the results reported by Senapati et al. (1992); and Behera et al. (1995). They observed overall performance index of 0.49 -0.57 for finger millet and 0.75-0.88 for dryland paddy. The overall performance index of seed drills manufactured in Malwa plateau was the highest (0.74) and followed in Nimar valley (0.71) for sowing of wheat. For soybean crop, the overall performance index was the highest (0.72) for machinery manufactured in Malwa plateau. The higher overall performance index of seed drills manufactured in Malwa plateau has a direct correlation with the yield of soybean and wheat crops in the region. The yield of both the crops in the region was higher as compared to other regions of MP (**Table 2**). The overall performance indices of seed drills manufactured in Satpura (for wheat) and Kymore plateau & Satpura hills regions (for soybean) were minimum among the selected agro-climatic regions.

Conclusions

An overall performance index based on precision, performance and manufacturing quality was proposed and calculated for the selected seed drills manufactured in different agro-climatic regions of Madhya Pradesh. The following conclusions may be drawn from the study.

(a) The precision indices of seed drills manufactured in Vindhya plateau and Malwa plateau regions were the highest for sowing of wheat and soybean seeds, respectively.

(b) There was a significant difference in the effective field capacity and field efficiency among the seed drills manufactured in different agro-climatic regions affecting performance of seed drills.

(c) Among the manufacturing quality parameters, hardness of furrow opener conformed to BIS standards. However, on average 6 parameters of hitch pyramid conformed to BIS recommendations.

(d) The highest values of overall performance index were 0.74 and 0.72 for sowing of wheat and soybean crops, respectively for seed drills manufactured in Malwa plateau of Madhya Pradesh.

(e) The developed overall performance index will help in comparative performance evaluation for seed drills and selection of right seed drills.

REFERENCES

Adake, R. V., Mayande, V. M., Kumar, A. C. S., Thyagarj, C. R., Mandal, U. K., Srinivas, I., Reddy, B. S. and A. L. Pharande. 2010. Performance indices of farm implements for in-situ incorporation of biomass (green manural) in rainfed situations. Indian Journal of Dry land Agricultural Research and Development, 25(1), 61-69.

Afzalinia, S., Shaker, M. and E. Zare. 2006. Performance evaluation of common grain drills in Iran. Canadian Biosystems Engineering, 48(2), 39-43.

Andrews, S. S., Karlen, D. L. and J. P. Mitchell. 2002. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, ecosystems & environment, 90(1), 25-45.

Anonymous. 1996. Report of the Sub-Group on Agricultural Implements and Machinery for Formulation of 9th Five Year Plan, Government of India.

Anonymous. 2011. Farm Machinery. National Portal Content Management Team, Available from https://archive.india.gov.in/citizen/agriculture/index.php?id=58 (accessed on 24.10.2017).

Anonymous. 2017a. Annual report 2016-17, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf (accessed on 25.09.2017)

Anonymous. 2017b. Online Agricultural Research Data Book 2017. Indian Agricultural Statistics Research Institute, New Delhi, India, http://iasri.res.in/agridata/17data/HOME_17.HTML (accessed on 24.10.2017).

Behera, B. K., Sahoo, P. K., Swain, S. and D. Behera 1995. Evaluation of Seeding Devices for Dryland Paddy. Agricultural Mechanization in Asia Africa And Latin America, 26, 17-21.

BIS. 1983. Share for Tractor-operated Mould board Ploughs, IS 10691: 1983. Bureau of Indian Standards, New Delhi, India.

BIS. 1997. Agricultural Wheeled Tractors - Rear-Mounted Three-Point Linkage Categories 1, 2, 3 and 4, IS 4468, Part1:1997. Bureau of Indian Standards, New Delhi, India.

BIS. 2000. Sowing equipment-seed-cum-fertilizer drill-specification (second revision), IS 6813, Bureau of Indian Standards, New Delhi, India.

Chaudhuri, D. 2001. PM -Power and Machinery: Performance Evaluation of Various Types of Furrow Openers on Seed Drills- a Review. Journal of agricultural engineering research, 79(2), 125-137.

Cupiał, M., Szeląg-Sikora, A. and M. Niemiec. 2015. Optimisation of the machinery park with the use of OTR-7 software in context of sustainable agriculture. Agriculture and Agricultural Science Procedia, 7, 64-69.

Maleki, M. R., Mouazen, A. M., De Ketelaere, B. and J. De Baerdemaeker. 2006. A new index for seed distribution uniformity evaluation of grain drills. Biosystems engineering, 94(3), 471-475.

Mehta, C. R., Chandel, N. S. and T. Senthilkumar. 2014. Status, challenges and strategies for farm mechanization in India. Agricultural Mechanization in Asia Africa and Latin America, 45(4), 43-50.

Mehta, C. R., Chandel, N. S., Senthilkumar, T. and K. K. Singh. 2014. Trends of agricultural mechanization in India. Economic and Social Commission for Asia and the Pacific (ESCAP) Policy Brief, 2.

Mehta, C. R., Singh, K. K., Gholap, B. S. and R. Patle. 2018. Status of Mechanization of Potato Cultivation in India. Agricultural Engineering Today, 42(2), 37-44.

NAAS. 2016. Practical and affordable approaches for precision in farm equipment and machinery, Policy Paper No. 84, National Academy of Agricultural Sciences, New Delhi,India, 16.

Senapati, P. C., Mohapatra, P. K. and U. N. Dikshit. 1992. Field evaluation of seeding devices for finger-millet. Agricultural Mechanization in Asia, Africa, and Latin America, 23(3), 21-24.

Senthilkumar, T., Chandel, N. S., Mehta, C. R. and B. S. Gholap. 2017. Trends of Tractorization in Indian Agriculture. Agricultural Mechanization in Asia Africa and Latin America, 48(2), 50-59.

Singh, G. 2015. Agricultural mechanisation development in India. Indian journal of agricultural economics, 70, 64-82.

Singh, R. C., Singh, G. and D. C. Saraswat. 2005. Optimisation of design and operational parameters of a pneumatic seed metering device for planting cottonseeds. Biosystems engineering, 92(4), 429-438.

Singh, S. 2016. Data book on Agricultural Mechanization in India. Agricultural Machinery Manufacturers Association, India.

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