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Effect of metering speed and hopper capacities on the discharge and application rates of a locally developed maize planter

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ABSTRACT

The researches that have been carried out on grain crops production in different parts of the country (Nigeria) have revealed the great importance of the crops. The growing utilization of these crops by food processing industries and livestock feed mills demands for rapid production through mechanization, particularly in planting. The research was aimed at determining the effect of speed and hopper capacity on the working parameters of a maize planter. The pre-design experimentation was carried out on yellow maize (Zea mays) and the evaluation of the planter carried out in the respect of the dependence of the application and discharge rates on metering speed and hopper capacity. The recorded geometric mean diameter and cell diameter of the maize grains are 8.26 mm and 10 mm respectively with groove depth 8 mm. It was also revealed at all hopper capacities that the discharge and application rates had uniform trends which showed that the effect of hopper capacities is not significant ($P<0.05$). The effect of metering speed on these parameters is highly significant ($P<0.05$). The planter has seed damage efficiency of 98% at an optimum metering speed of 45 rpm. The planter, when tested on the field had a capacity of covering 0.28 ha/hr with the average discharge and application rates of 16.02 kg/hr and 58.82 kg/ha respectively. The regression analysis showed that the discharge and application rates were not significantly affected by hopper capacities but the metering speed has significant effect on both the discharge and application rates at probability level of 0.05.

Keywords: Grain crops, maize planter, application rate, discharge rate, metering speed.

1. INTRODUCTION

Planting began with the use of hands and later the use of stones, hand tools and mechanized form of planting (Yasir et al., 2012). The traditional or manual methods of planting maize resulted in drudgery, inaccurate spacing, injurious to the farmers and also affect the size of the farm land (Kumar et al., 2015; Soyoye et al., 2016). Seed planting machine is a device which helps in the sowing of seeds in a desired position, thereby assisting the farmers in saving time and reducing cost. The major operational requirements of the plants are to house or carry the seeds, release the seeds in rows at required depth and also maintained the intra-row spacing (Odumal et al., 2014; Soyoye et al., 2016). However, in fabricating the form of this mechanized planting equipment, some properties of the plant which is to be planted must be determined in order to accurately specify the design considerations (Jouki and Khazaei, 2012; Soyoye et al., 2018). The physical properties such as size, shape, axial dimensions, roundness and sphericity helps to determine the maximum size cells in the seed plate, the weight of the grains help in the material selection for the frame of the planter, the bulk density and moisture content helps determining the interaction between the grains and the selected materials for the hopper of the planter (Jayan and Kumar, 2004). The mechanical properties such as the angle of repose helps to ensure free flow of seed in the hopper Jayan and Kumar, 2004, the terminal velocity helps to determine the flow of the seed in air between the point of discharge and impact on the soil. The shear stress and impact stress helps to determine the amount of pressure the seed plate should apply on the seed. These properties help in specifying the design considerations of planting equipment because it will be a waste of time, resources, effort and money if after fabricating, and the machine fails to deliver up to expectation.

To successfully establish crops, a planter should be able to:

1. Open a furrow;
2. Meter the seed;
3. Deliver the seed to, and place the seed appropriately in the furrow;
4. Cover the seed in the furrow;
5. Firm the seedbed; and
6. Perform other functions as required, e.g. weed control, apply crop chemicals, etc.

These functions must be performed at an acceptable forward speed and with a high degree of reliability. Not all planting machines are capable of performing, or necessarily need to perform all the functions. Nevertheless, the ability to perform all functions improves planter flexibility and prospect of crop establishment, particularly when sub-optimal conditions for crop establishment exist at the time of planting (Murray et al., 2006).

The early planters consisted of hoe with a small container. After digging a hole, the farmer releases the seed and presses it firmly into the soil with his foot (Deere, 1981; Kepner, 1978). Gupta and Herwanto (1992) reported the various versions of existing hand operated planters, which include “Jab” planter, rotary injection planter, auto feed “punch” planter, and hand-operated precision planter. The limitation of the conventional “Jab” planter is the time required by the user to select and deposit into the planter funnel the correct number of seeds and the desirability of locating seed in the base point of the opener at the correct time of “Jabbing”. Metering of the desired number of seeds remains the problem of rotary injection planter.

Kumar et al. (1986) designed a manually operated seeding attachment for animal-drawn cultivator. A moderately accurate metering of seed was designed for proper distribution of seed in furrows and minimum number of moving parts was ensured so that farmers may operate and maintain the machine easily. Bamgboye and Mofolasayo (2006) carried out performance evaluation on a manually operated two-row okra planter by conducting field and laboratory tests. The investigation carried out included the determination of the variation in weight of seeds discharged from the two hoppers, the percentage damage of seeds, and the average intra-row spacing of seeds. In the same trend, (Adisa and Braide, 2012) designed and developed a template row planter to improve planting efficiency and reduce drudgery involved in manual planting method. It was also reported that the planting of seeds and fertilizer application accuracies were increased and effective through the use of the designed.

Yasir et al. (2012) designed and tested a tractor mounted pneumatic precision metering device for wheat which was applied to wheat seeding to overcome seed damage, seed loss and non-uniform distribution. The performance of the device, including quality of feed index, multiple index, miss index and seed rate expressed in number of kernels per meter length, was investigated under laboratory conditions in Wuhan using a test stand with camera system. The results revealed that the rotating speed and negative pressure and their interactions had a significant effect on these variables. Ugwuoke et al. (2014) focused their work on the design and fabrication of a manually operated single row maize planter capable of delivering seeds precisely in a straight line with uniform depth in the furrow, and with uniform spacing between the seeds.

2. MATERIALS AND METHODS

2.1. Pre-design Experimentation

DMR-LSR yellow maize (*Zea mays*) was used for the experimentation work, which was procured at the Institute of Agricultural Research and Training Obafemi Awolowo University, Nigeria. A pair of vernier caliper was used to measure the axial dimensions of the material including the length, breadth and thickness. The model used is the Gilson Vernier Caliper with calibration of 20 cm with error of 0.05 mm. The weighing can was used to hold the materials in the oven when determinig the moisture content of the materials. The weighing balance used was the Electronic Precision Balance with model JA303P, number 1505601, Max weighing 310 g and readability 0.001 g. The sliding box was the equipment used to determine the angle of friction and the coefficient of friction. It was made of ply-wood with an attached protractor used for determining and reading-out the angles.

Plate 1. The Assembled Planter

2.2. The Designed Motorized Planter

The motorized planter is a machine that is designed to tackle the major constraint and challenges encountered in the use of the existing planters and planting systems (low, productivity, drudgery, cost, safety etc.). The metering device is the key component of the precision grain crop planter. A ground wheel was used to provide the drive to the metering device in the existing planters. However, the rotation of the metering wheel on the ground was highly resisted such that it easily slips. Therefore, an electrically driven and controlled system is incorporated into the planter. Instead of the conventional ground wheel, the system uses an electric motor to drive the seed metering device which could reduce the influence of non-uniformity caused by ground wheel slippage. The seeder of the planter was considered to be constructed using two separate seed boxes, one for each row (Plate 1). Seeds were distributed and metered by vertical seed plates with peripheral seed cells. The seeding mechanism was mounted on a metal frame supported on the chassis. It was also made versatile to accommodate different types of grains through the inter-row spacing adjustment mechanism thereby enhancing the acceptability of the planter by peasant farmers. The seed monitoring unit was fixed between the metering unit and the delivery unit. The seed monitoring unit comprises of the seed counting sensors, seed valve and plunger. This unit was introduced into the planter to count, record the numbers for storage and regulate the flow of seeds through the seed delivery tube.

2.3. Machine Testing

The machine was tested in the Laboratory where experiments were conducted to test the metering mechanism. The planter was tested electrically by connecting a dc motor to the metering shaft using a chain and sprocket connection of ratio 1:1. The motor was allowed to rotate and the quantity of seeds received over a period time was weighed and recorded as displayed on the display screen. The seed visible damage was also estimated, by operating the planter at various speeds. The planter was also operated at different levels of seeds in the hopper. It was evaluated in the following hopper conditions;

1. When the hopper was filled with seeds at its full capacity
2. When the hopper was filled with seeds at its 75% capacity
3. When the hopper was filled with seeds at its 50% capacity
4. When the hopper was filled with seeds at its 25% capacity

The effect of these hopper capacities on the seed discharge and application rate was noted, recorded and tabulated. At each instance, Equations 1 and 2were used to calculate the discharge and application rates respectively. The experiment was repeated by noting and recording the number of seeds dropped over a period of time and the number of damaged seeds were also noted.

$$Discharge\ rate = \frac{Quantity\ of\ seed\ dropped}{Time\ taken} \qquad (1)$$

$$Application\ rate = \frac{Quantity\ of\ seed\ dropped}{Area\ of\ land\ covered} \qquad (2)$$

3. RESULTS AND DISCUSSION

The capacity of the planter was evaluated based on the discharge rate and application rate of the metering unit. These parameters were in turn used to determine the optimum operation conditions of the planter. Table 1 shows the average capacity of the planter at the hopper full capacity (100% hopper capacity). It was revealed from the table that the total seed discharged (dropped) at the seed tube increased with decrease in the speed of the planter (metering plate speed). This is due to the fact that at high speed the seeds do not have enough time to drop into the cell groove. Also, at high speed the seeds had high impact on the wall of the metering cells thereby resulting in the bouncing around of the seeds. The implication of operating the planter at these high speeds is that it results in high missing index on the field. It was revealed from the results that the planter has a steady and uniform discharge rate and application rate irrespective of the hopper capacity (level of seeds in the hopper) (Figures 1 and 2). It was shown from the figures that the discharge rate and the application are inversely related. The optimum speed of the planter was chosen to be the point of interception between the discharge rate and the application rate; it is taken to be 45 rpm. This point was justified by Figure 3 which shows the efficiency of the planter at different metering speeds and varying hopper capacities. It was revealed that at all the hopper capacities the highest efficiency of 98% was recorded at the metering speed of 45 rpm at the linear speed of 1.30 m/s. The field capacity of the planter was determined to be 0.28 ha/hr with the average discharge and application rates of 16.02 kg/hr and 58.82 kg/ha respectively. The result could be compared with what was recorded by Karim et al. (2015) when they evaluated a drum seeder with urea super-granule application and recorded an optimum roller speed of 23 rpm when the seeder was manually pulled. On the other hand, Hossein et al.(2012) recorded a metering speed of 41.5 rpm at the planter travel speed of approximately 1 km/hr during the determination of some design parameters for roller type seed metering device such as roller speed, travel speed, length and depth of groove for tomato seeds precision planting.

Table 1. Machine performance at 100% hopper capacity in 60 seconds

S/N	Speed rpm	Speed (m/s)	Total seed dropped (kg)	Seed damage (kg)	Discharge rate (kg/hr)	Application rate (kg/ha)	Efficiency (%)	Field capacity (ha/hr)
1	80	2.305	0.214	0.0189	12.84	25.79	91.17	0.50
2	70	2.017	0.232	0.0136	13.92	31.96	94.14	0.44
3	60	1.729	0.251	0.0106	15.06	40.33	95.78	0.37

4	50	1.441	0.272	0.0063	16.32	52.45	97.68	0.31
5	40	1.152	0.262	0.0059	15.72	63.15	97.75	0.25
6	30	0.864	0.202	0.0049	12.12	64.92	97.57	0.19
7	20	0.576	0.134	0.0045	8.04	64.60	96.64	0.13

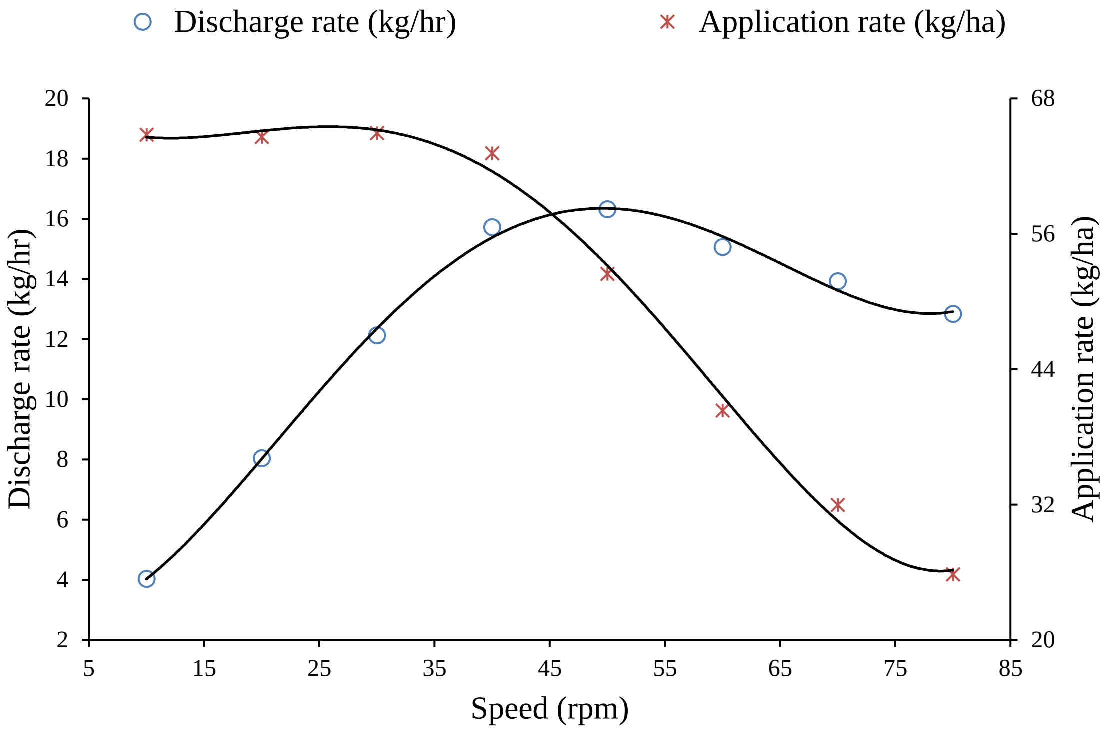

Figure 1. The discharge and application rates of the planter at 100% hopper capacity

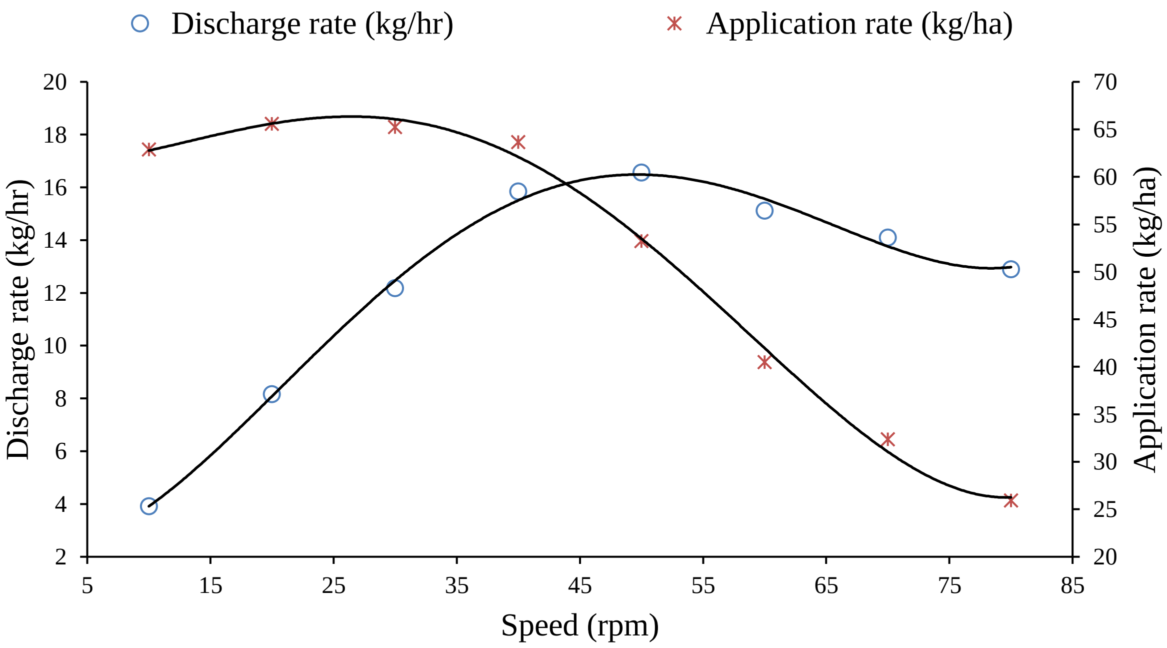

Figure 2. The discharge and application rates of the planter at 25% hopper capacity

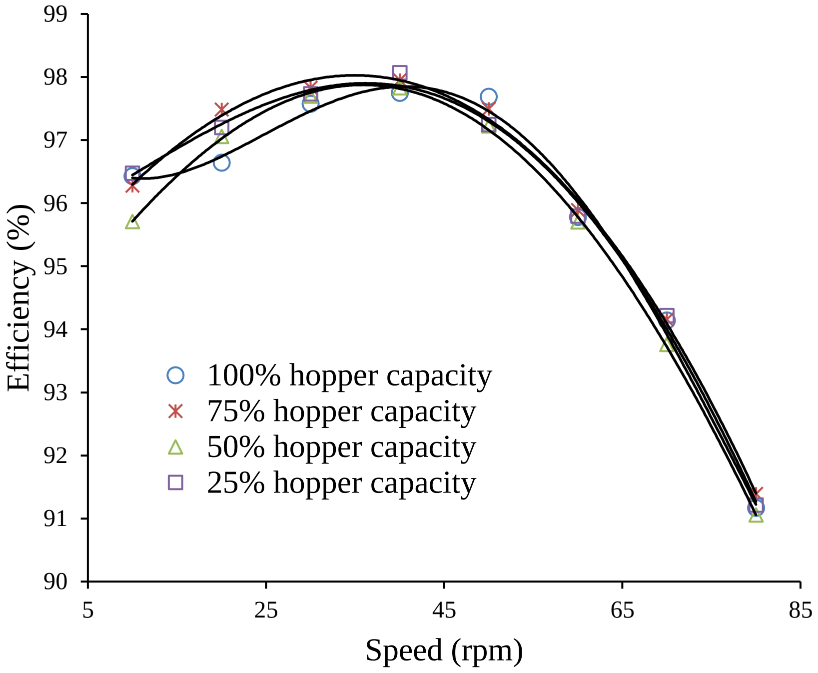

Figure 3. The efficiency of the planter at different hopper capacities

The effect of the metering speed on the application and discharge rates at different hopper capacities is shown in Figures 4 and 5. It was revealed from the Figures that both the application and discharge rates have an increasing trend at the initial (low rotational speed) stage. A decreasing trend was observed between 35 rpm and 45 rpm. The Figures also showed that at all hopper capacities, the application and discharge rates exhibit the same trend (uniform trend). This shows that the effect of hopper capacities is not significant at P<0.05. The theoretical field capacity of the planter was 0.28 ha/hr with the average discharge and application rates of 16.02 kg/hr and 58.82 kg/ha respectively for maize crop. The result is an improvement to what was recorded by Bamgboye and Mofolasayo (2006) when they carried out performance evaluation on a manually operated two-row okra planter by conducting field and laboratory tests where the discharge rate of 0.36 kg/hr was recorded. Also, a field capacity of 0.260 ha/hr was reported by Odumalet al. (2014). In the same trend, the planting rate of the template row planter that was designed by Adisa and Braide(2012) was found to be 0.20 ha/hr.

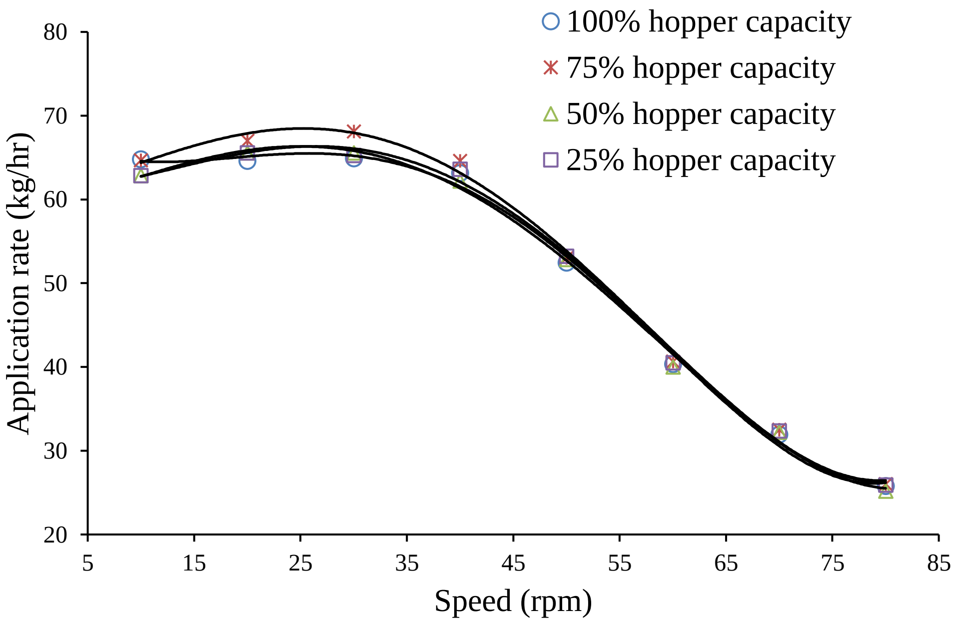

Figure 4. Effect of speed on application rate using four different hopper capacity for maize

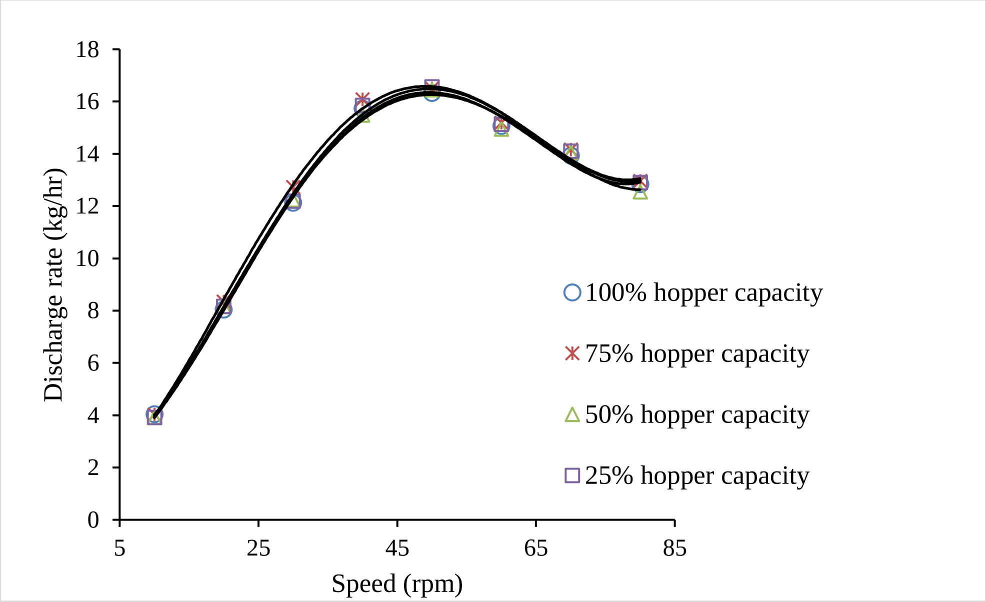

Figure 5. Effect of speed on discharge rate using four different hopper capacity for maize

Table 2 shows the statistical t-test carried out on the discharge and application rates. The tests show that the discharge and application rates are not significantly affected by hopper capacities but the metering speed has significant effect on both the discharge and application rates at probability level of 0.05. The surface plots in Figures 6 and 7 confirmed the results of the t-tests that the discharge and application rates are not significantly affected by hopper capacities but the metering speed has significant effect on both the discharge and application rates. This is because, the application and discharge rate displayed a constant trend at different hopper capacity irrespective of the metering speed on the surface plot (Figures 6 and 7).

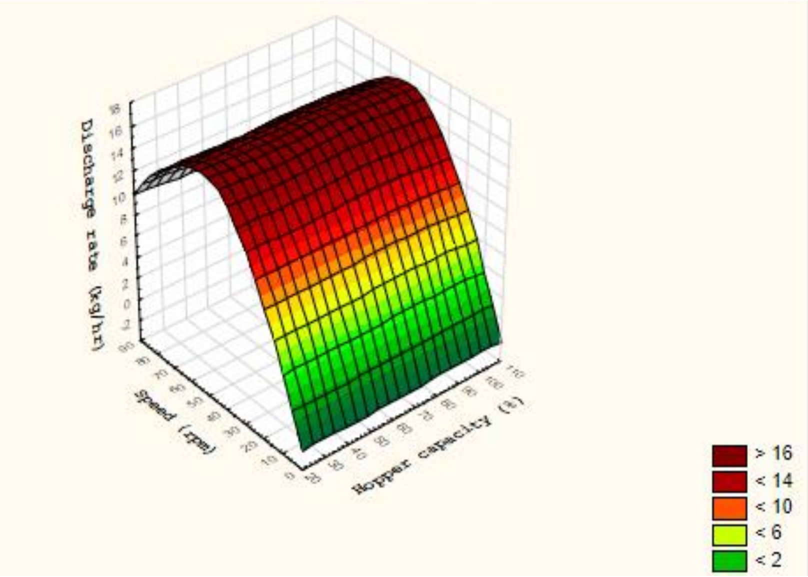

Figure 6. Effect of metering speed and hopper capacity on discharge rate

Table 2. Statistical t-test on machine parameters

Source	Value	Standard error	t	Pr> |t|	Lower bound (95%)	Upper bound (95%)
Intercept	6.8985	2.9562	2.3336	0.0270	0.8430	12.9540
Hopper capacity	0.0010	0.0432	0.0227	0.9820	-0.0875	0.0894
Rotational speed (rpm)	0.1207	0.0585	2.0609	0.0487	0.0007	0.2406
Hopper capacity*Rotational speed (rpm)	0.0000	0.0009	-0.0248	0.9804	-0.0018	0.0017

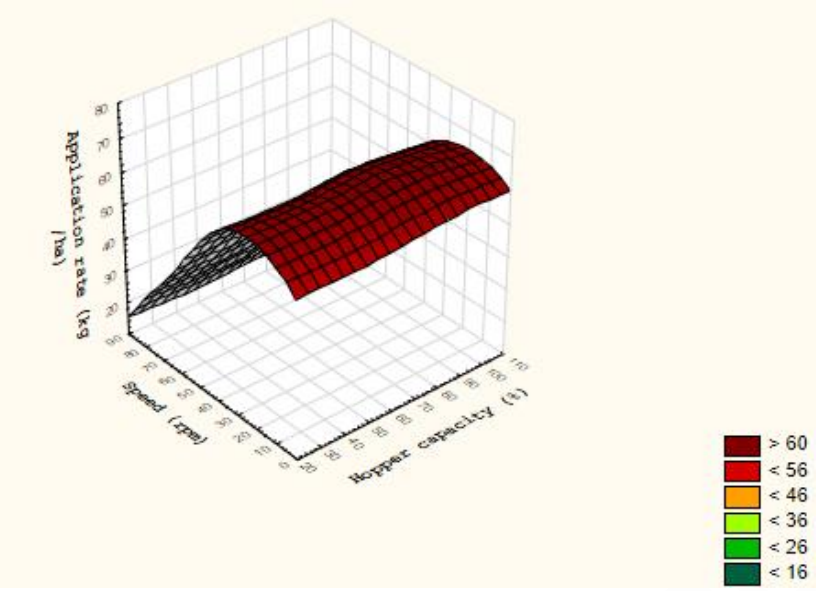

Figure 7. Effect of metering speed and hopper capacity on application rate

4. CONCLUSION

An indigenous maize planter was evaluated to determine its optimum working parameters and based on the results, the following conclusions were made.

1. Irrespective of the hopper capacity, the designed planter has uniform discharge and application rates. The discharge rate and application rate at all the hopper capacities exhibited the same trends.
2. The field capacity of the planter is 0.28 ha/hr with the average discharge and application rates of 16.02 kg/hr and 58.82 kg/ha respectively.
3. The effect of damages on the seeds was not significant at low metering speed of between 10 rpm to 45 rpm. At speeds greater than 45 rpm, significant and visible damages were done on the seeds at $P<0.05$.

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