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Design and development of tractor operated onion set planter

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ABSTRACT

The paper describes the design and development of planter for planting onion sets of aggregatum group onions Onion (*Allium cepa* L.) in close-spacing. The onion set planter developed consisted of onion set planting unit, seed hopper, standard three point hitch for mounting to tractor, main frame, furrow opener, ground wheel, and drive transmission mechanism. The onion set planter was evaluated in the laboratory for its performance. The performance indices namely multiple index, miss index, quality of feed index, precision, mean and standard deviation of onion set planter were 0.05, 0.18, 0.77, 0.27, 11.71 and 5.22 cm' respectively. The precision of 0.27 was in the acceptable region for indicating the encouraging performance of planter in terms of planting single sets. The tractor operated onion set planter was tested in the field for its performance. The onion sets were graded into four grades. All the four grades of the onion sets were planted by the prototype onion set planter. Plant to plant spacings were 9.34±1.530, 10.35±2.162, 11.50±2.305 and 12.64±2.758 cm for the grades I(2-3 g weight), II(3-4 g weight), III(4-5 g weight) and IV(5-6 g weight) on 12 DAP respectivety. The field capacity of the onion set planter was 0.15 ha./h. The cost of operation was ₹ 4 150/ha. The cost saved by using onion planter over manual planting was about 30%.

Key words: Aggregatum type onion, Inclined plate planter, Planting, Seeder

Onion (*Allium cepa* L.) is one of the most important vegetables consumed widely. Aggregatum group onions are mainly grown in Tamil Nadu State due to the food habit in Tamil Nadu and also to have an early crop. Area under onion cultivation in Tamil Nadu is increasing every year from 33,800 ha during 2010-11 to 37, 120 ha during 2011-2012 to 37,700 ha during 2012-2013. Though there are three systems of planting, viz. direct seeding, transplanting and planting sets (small dry bulbs), the planting system for aggregatum group onion is planting sets. Sets are onions that are planted from seed last year. Sets are available from onion traders and markets. Few farmers sometimes store the current season harvested onions for next season for planting material purpose. Onion sets that are firm and marble size but have not sprouted are used as planting material. Big sets are split into two bulbs otherwise they produce a flower stalk very early.

When compared to any other vegetable crops, onion is planted with very close spacing. Spacing between sets in rows is about 10 cm and plant is 20 cm. Due to this, the labour requirement for planting is high, also labourers demand higher wages for onion planting. This leads to higher cost of cultivation. The capacity of man power is very low about 0.05 ha./man/day and payment for planting is 11.9% of total cost of production. Also manual planting is cumbersome and time consuming. A tractor operated two row onion set planter for planting onion sets was developed at Texas Tech University, Texas. The metering mechanism used was horizontal plate type (Sadhu 1982). Different types of available planters were evaluated for planting onion sets and it was reported that uniformity of onion set distribution within row depends to a great extent on the performance of the metering devices of the planting machine, where metering devices (mechanical and pneumatic) are functioning according to seeds dimensions and cell conditions Helmy *et al.* 2005, Tayel *et al*. 2001, Amin *et al*. 1998 and El-Sahrigy *et al.* 1991.

Though not much attempt has been made to develop a onion set planter, different models of garlic planter have been developed in different parts of the world wherein the planting material for garlic (*Allium sativum* L.) is also individual garlic cloves. Rocha *et al.* (1991) developed a manually operated planter for garlic bulbs mounted on two bicycle wheels and equipped with a toothed belt distribution mechanism. The toothed rubber belt was equipped using the sponge teeth measuring 25 × 47 mm and 25 mm high. In field tests using the prototype equipment, bulbs were spaced at 5 bulbs per m. Jarudchai *et al*. (2002) designed and developed a power tiller attached garlic planter adopting bucket type metering device. Bakhtiari and Loghavi (2009) designed and developed a tractor-mounted, ground-wheel

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Fig 1 Tractor operated onion set planter

driven, triple unit, row crop precision planter capable of planting three rows of garlic cloves on each raised bed. The clove metering mechanism used was drum seeder and the results showed that the machine was capable of planting 220 000 plants/ha at the seeding depth and spacing of 12.3 and 22.7 cm, respectively. Also, miss index, multiple index and seed damage were measured as 12.23, 2.43 and 1.41%, respectively. Jiraporn *et al*. (2010) designed and developed a tractor operated 10-row garlic planter. The metering mechanism was buckets mounted on disc. The results showed that the buckets had maximum scoop efficiency for one clove was 90.42% at a disc revolution of 40 r/min and at a forward speed 1.67 km/h. The seed delivery tube was 30cm above groud level. The seed delivery tube above ground level was 30 cm. The field capacity was 0.13 ha/man-h and plant spacing was 11.73 cm. The shoe type furrow opener was used. The precision of this 10-row garlic planter was 21.0%. The aim of this study was to develop and evaluate a prototype tractor drawn onion set planter.

MATERIALS AND METHODS

The crop parameters are important in the design of planters. The crop parameters considered for the development of onion set planter were row to row spacing, plant to plant spacing and number of sets per hill. The planting pattern generally followed for multiplier onion is paired row. The spacing within two rows is 20 cm and the spacing between row is 30 cm. Keeping this in view, a planter for three paired rows, having three hoppers and onion set metering mechanism was designed and developed. Each onion set metering mechanism had a pair of onion set metering disc and mounting arrangement. The furrow opener was designed based on the crop requirements. Thus, the prototype tractor operated onion set planter consisted of i) onion set planting unit, ii) seed hopper, iii) standard three point hitch for mounting to tractor, iv) main frame, v) furrow opener, vi) ground wheel and vii) drive transmission mechanism (Fig 1).

After studying the different mechanism adopted for planting bold seeds, garlic and onion sets, inclined plate metering mechanism was considered as metering mechanism for planting onion sets in this present study. The concept of unit planter was adopted and each unit had a seed hopper and a pair of metering discs. The onion set metering mechanism consisted of a i) onion set metering disc, ii) onion set disc holding plate, iii) shaft for transmitting drive to the disc, iv) seed disc mounting board, v) bush for mounting shaft, vi) bevel gears and vii) spring.

From the biometric data of onion sets it was observed that the width of onion sets ranged from 17.15 ± 0.35 mm to 29.05 ± 0.47 mm. The crop–machine studies showed that the width of cells should be in the range of 25 to 30 mm for satisfactory cell fill for all sizes of onion sets and also the cells should be designed to ensure both face entry and edge entry. Hence each cell was machined on the disc in such a way that the cell would have an inclination in two directions, i.e. i) towards the centre of disc (β_1) and ii) along the tangential direction (β_2). As the disc rotates, the cells made with this angle would enable to pick up onion sets from the reserve hopper adjacent to seed disc and drop them vertically. The radial inclination 45º(β_1) was equal to the inclination of seed plate so as to ensure vertical drop of the onion set. The tangential inclination (β_2) was fixed as 25º based on existing design of inclined plate for seeds. Since a paired row system is to be adopted, a pair of metering discs was designed to fit inside each seed hopper and the discs were made to rotate opposite to each other. Hence, cells were formed in clockwise direction in one disc and in anti clock wise direction in the other disc.

In order to provide a smooth and free rotation to the onion set metering disc, the discs were mounted on hylum board with necessary screw fittings. A bevel gear was fitted at the end of the shaft to transmit the drive to the onion set metering disc from the main shaft. The onion set hopper had two portions, viz. i) storage hopper and ii) reserve hopper for onion set pick up. The storage hopper was rectangular in shape. The bottom of the hopper had a slope and the angle of slope was kept based on emptying angle of repose of seed onion. The front side wall (onion set metering disc side) of hopper had a slope of 45º and the back side wall (tractor

side) of hopper also had a slope of 45º. A rectangular opening of 120 mm by 120 mm was made at the sloped side of front wall of hopper to feed the seed onions to the reserve hopper. A matching sliding door was fitted with necessary fittings to open and close the opening. The overall height of onion set hopper was 630 mm. The hopper had a volume of 80 liters and hence can hold 34 kg of sets (4-5 g) having bulk density of 429 kg/m^3. Hence, for one fill of hopper, there will be around 7800 no. of sets (4.397 kg/1000 sets) and at a spacing of 10 cm, a hopper can supply seed for 2 rows of 390 m length. This will be optimum considering the practical difficulty of accommodating larger hopper size. As the operating width of onion set planter would be 1.5 m, 16 fillings of hopper would be required for planting one hectare of land.

A shoe type furrow opener with wings was fitted to the main frame in front of planting unit so that the furrows opened are kept open till the seed onions are deposited in the furrow. The basic design of the implement frame was adopted from commercially available inclined plate planters. The main frame supported the onion set planting unit, ground wheel, drive transmission system, furrow opener and standard tractor three point hitch. The main frame had a major dimension of 1700 mm length and 580 mm width.

Laboratory testing of onion set planter: The performance of the tractor operated onion set planter was tested in the laboratory. The onion set planter was mounted to a tractor and operated at a forward speed of 1 kmph. The spacing between the dropped onion sets was measured. The performance indices of a planter namely multiple index, miss index, quality index of feed index and precision along with mean and standard deviation keeping theoretical spacing as base was calculated from the measured spacing between dropped onion sets (Kachman and Smith 1995).

Field evaluation of onion set planter: The performance of onion set planter was evaluated in the field for singulated planting of onion set. The field trials were conducted to evaluate the performance of the prototype planter for planting four grades of onion sets, Grade I (2-3 g weight), Grade II (3-4 g weight), Grade III (4-5 g weight) and Grade IV (5-6 g weight). The seedling emergence was recorded 12 days after planting. After plant emergence, the spacing between seedlings was measured.

RESULTS AND DISCUSSION

The results of performance indices namely multiple index, miss index, quality of feed index, precision, mean and standard deviation of onion set planter are presented in Table 1. The index precision represents the variability in singles. From Table 1, it was observed that the precision was 0.27. This precision was very well in the acceptable region for indicating the good performance of planter in terms of planting single sets (Katchman and Smith 1995). Katchman and Smith (1995) suggests that the theoretical upper limit for precision is 50%. The upper limit of 50% occurrs when half the spacings are at the lower limit of the target range and the other half are at the upper limit of the target range. A practical upper limit on the value of precision is 29%. A precision of 29% would be indicative of all the spacing being spread uniformly within the target range.

Table 1 Performance indices of onion set planter during laboratory test run

Performance indices	Value
Multiple index	0.05
Miss index	0.18
Quality of feed index	0.77
Precision	0.27
Mean, cm	11.71
Standard deviation, cm	5.22

Table 2 Plant spacing for different grades of onion set planter

	Plant spacing, cm			
	Grade I (2-3 g weight)	Grade II (3-4 g weight)	Grade III (4-5 g weight)	Grade IV (5-6 g weight)
Mean, cm	9.34	10.35	11.50	12.64
Standard error of mean	0.782	1.103	1.176	1.407
95% confidence limit	9.34± 1.530	10.35± 2.162	11.50± 2.305	12.64± 2.758

Fig 2 Onion crop planted by tractor operated onion set planter (12 DAP)

From the above observation, it was concluded that the tractor operated onion set planter had good performance for planting single onion sets at the required spacing of 10 cm between plants in a row at the operating speed of 1 kmph during test run in the laboratory.

Field testing of onion set planter on emergence of onion crop

Four grades of onion sets were planted by the prototype planter and spacing between the emerged seedlings were measured and recorded on 12 DAP (Fig 2). The results are given in Table 2. The plant to plant spacings were 9.34±1.530, 10.35±2.162, 11.50±2.305 and 12.64±2.758 cm for the grades I(2-3 g weight), II(3-4 g weight), III(4-5 g weight) and IV(5-6 g weight) respectively.

(a) Under lab trials with the tractor operated onion set planter developed for planting onion sets, the performance indices of multiple index, miss index, quality of feed, precision, mean and standard deviation were 0.05, 0.18, 0.77, 0.27, 11.71 and 5.22cm. Hence, the planter could plant the onion sets at a spacing of 11.71 ± 0.96 cm.

(b) Four grades of onion sets were planted by the prototype planter and spacing between the emerged seedlings were measured and recorded on 12 DAP.

(c) The plant to plant spacings were 9.34±1.530, 10.35±2.162, 11.50±2.305 and 12.64±2.758 cm for the grades I(2-3 g weight), II(3-4 g weight), III(4-5 g weight) and IV(5-6 g weight) respectively.

(d) The field capacity of the onion set planter was 0.15 ha/h. The cost of operation was Rs.4 150/ha. The cost saved by using onion planter over manual planting was about 30%.

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