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DEVELOPMENT AND LABORATORY TESTING OF MAIZE PLANTER-CUM-LIQUID FERTILIZER APPLICATOR

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ABSTRACT

A study was conducted at Agricultural Engineering Research Workshop, Faisalabad, Pakistan during the year 2014 to develop and test maize planter-cum liquid fertilizer applicator. At present most of the maize crop is planted manually. After soil preparation, ridges are made by the tractor mounted ridger and the seed is planted manually at the shoulder of ridge. Human error and laborious work has made it quite difficult for the farming community. Some efforts were made by different organizations to mechanize its planting system but no workable solution was presented. For the purpose of complete mechanization in maize planting and to introduce band placement of phosphoric acid for achieving higher P use efficiency, a "Band Placement Planter-Cum- Liquid Fertilizer Applicator for Maize" was designed, developed and its laboratory testing was carried out for evaluation of its different components. The planter was produced from locally available material and was kept at low weight for having ease in operation with the tractor. A set of inclined aluminium star disc was used in two seeding units and each seeding unit was pivoted to adjust the angle of the seed disc for assurance of single seed drop. Chain-sprocket power transmission system provides inter seed distance of 6 – 9 inch. The ridger was designed to attain the angle of penetration (α) of 26^o and the ridge shaper is placed behind the ridger to have a well configured and compact ridge, to provide favorable environment for seed germination. Front ground wheel provided a firm grip over the soil and diminished possible wheel slip. Orifice for gravity flow of diluted phosphoric acid (52% P_2O_5) provided a uniform liquid fertilizer application at proper place. During laboratory testing, minor error (2%) was observed in seed distribution.

KEYWORDS: **Maize planter; phosphoric acid; gravity; aluminum star disk; Pakistan.**

INTRODUCTION

In present scenario, usability of technology is linked with its cost-effectiveness and net profitability. Desire for swiftness in agricultural

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operations moved farmer's community to leave conventional methods of crop production and to adopt more sophisticated/efficient technology. Alongwith the other components used in agriculture, mechanization cannot be ignored for its ease in agricultural operations and rapidity in completion of the task at farm level. It has been estimated that use of agricultural machinery alone contributes upto 50 percent of production cost. As far as soil preparation is concerned, almost all sorts of agricultural machinery is available with farmers except sowing/planting machinery which is still scarce and farmers have to perform labour intensive job of placing the seed especially of maize manually in the soil.

Maize ranks 3rd among mostly grown crops in the world with an area of more than 118 million hectares with an annual production of about 600 million metric tons. In Pakistan, maize is the 4th largest grown crop after wheat, cotton and rice. The area under maize is over one million hectares with an average production of 3.5 million metric tons. Punjab contributes 39 percent of total area under maize and 30 percent of total production. KPK contributes 56 percent of total area and 63 percent of the production while 5 percent of total area and 3 percent of total production is contributed by Sindh and Balochistan provinces (17).

Favourable soil environment is required for seed germination and seedling establishment. Fine and compact bed is quite suitable for maize. The land with optimum moisture content provides good results after ploughing upto 20-25 cm deep or disking 2-3 times, immediately followed by planking. Maize can be sown on both flat soil as well as on ridges. Sowing on ridges is better in terms of water conservation. Ridges are made 75 centimeter apart with tractor drawn ridger. Seed rate of 20 kg per hectare is recommended for optimum plant population. Choka method or manual sowing is practiced for ridge sowing and a cost of about Rs. 2500-3000 per hectare is charged. In case of flat sowing, tractor drawn drill with 75 cm inter row distance is used. After drill sowing, thinning is done 10-15 days after emergence by maintaining 20-25 cm plant to plant distance. A plant population of 70,000 to 75,000 per hectare is inevitable to harvest optimum yield. Maize hybrids have the yield potential of more than 12 tons grains per hectare which is very high as compared with 3.68 tons per hectare the average yield of maize in Pakistan (4). The yield between the production and potential yields can be bridged up by adopting proper agronomic and mechanized practices.

Planting method is one of a crucial factor for improving crop yield. For maize crop sowing, different planting methods are practiced in the World. Inappropriate planting method results in barren plants. Ear and its size remains smaller, crop becomes susceptible to lodging, diseases and pests resulting in lower yield per unit area. Cardwell (8) concluded that among all agro-management practices, planting methods are of great importance that were in line with the results of a study conducted by Egrachenkov (9) who found that maize grown on ridges yielded 1000 kg per hectare, whereas the conventional planting on flat land produced 610 kg per hectare. A similar study was conducted by Abdullah *et al.* (1) and supported the view of Egrachenkov. They reported the significant increase in yield of maize from ridge planting of maize when compared with other planting methods. Jehan Bakht *et al.* (13) reported that planting methods and varieties had a significant role on number of plants per hectare at harvest and maximum number of plants per hectare was obtained from ridge planting, while minimum in broadcast. It may be due to high survival rate in ridge planting as compared with broadcast method. These results were in line with the findings of Siddique and Bakht (18) who concluded that ridge sowing improves seedling emergence. Amin *et al.* (2) also studied the impact of ridge sowing on maize production and found that if maize is sown on ridges it can maximize crop yield because it makes reasonable amount of nitrogen available to plants. Bar-Yousaf *et al.* (6) concluded that subsurface placement (banding) of phosphorus was found more efficient than surface fertigation as yield of the crop was higher for subsurface placement (25.2 t/ha) than surface fertigation (23.5 t/ha) whereas Munir *et al.* (15) investigated that banding of P-fertilizer through a seed-cum-fertilizer drill can save 50 percent fertilizer. Similar results were concluded by Latif *et al.* (14), Holloway *et al.* (11) and proved that efficiency of phosphoric acid as a cheaper alternative to common P fertilizer can further be increased markedly if applied through band placement. Borges and Mallarino (7) reported that band placement is one way to limit and concentrate the fertilizer addition near the root zone to enhance its utilization by the plant and avoid its fixation in soil due to less exposure of P fertilizer to soil surface area. Fortune and Burke (10) studied the seed environment for germination and reported that in a wet, cool climate, seeds should be placed in a dry part of the soil. In Ireland, this has been achieved successfully by sowing in the top of ridges.

In Pakistan, gap between potential yield and actual yield is due to use of inefficient methods of seed sowing and fertilizer application. It has been proved that maize sown on ridges alongwith placement of fertilizer in band can maximize crop yield. At present most of the maize crop is sown on the ridges, where tractor mounted ridger is used for making ridges and seeds are sown manually by choka, that is labor intensive and time consuming job. In order to address all the problems associated with maize sowing like ridge preparation, seed placement, fertilizer application and also band placement of fluid P source i.e. phosphoric acid, a compact and multi-functional band placement planter-cum-liquid fertilizer applicator is need of the time. For the purpose, a research study was launched at Agricultural Engineering Research Workshop, Faisalabad in collaboration with Nuclear Institute for Agriculture and Biology (NIAB) with following objectives:

(i). Design and Development of Maize Planter-cum-Liquid/solid fertilizer applicator.

(ii) Laboratory testing of metering system of the planter for seed, fertilizer and phosphoric acid

MATERIALS AND METHODS

This study was conducted at Agricultural Engineering Research Workshop, Faisalabad, Pakistan during 2014. Keeping in view the beneficial impacts of band placement of fertilizer either it is solid or liquid, and planting on ridges, a project was launched wherein a band placement planter-cum-liquid fertilizer applicator for maize was designed, fabricated and laboratory testing of its metering system was evaluated. The design and fabrication of different components of the band placement planter-cum-liquid fertilizer applicator for maize were made keeping in view the function to perform, fabrication facilities and skills, economics, simplicity of the design, social acceptability, knowhow of the end user, trend of local industry, local soil and environmental conditions.

DEVELOPMENT OF PLANTER AND ITS SPECIFICATIONS

Main frame

Main frame is the back bone of the machine and all other parts of machine are mounted on main frame (Fig. 1). MS Angle Iron 76 mm × 76 mm × 6 mm was employed to attain a compact and rigid structure. Overall length of main frame was 1651 mm and width was 610 mm to accommodate three ridging units, Seed metering system, liquid fertilizer reservoir, granular fertilizer box and ground wheel power transmission mechanism. A type three pin linkage system has been developed with mild steel flat 26 mm × 10 mm, and attached to the main frame to mount the machine with the tractor linkage system.

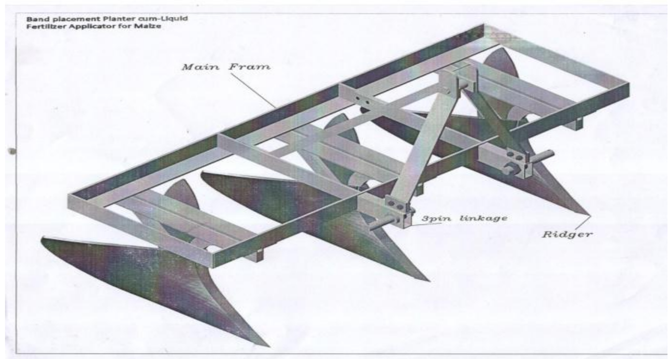

Fig. 1. Main frame with ridgers of the planter

Ground wheel

Power transmission to metering system is generally employed through the ground wheels. In Pakistan, mostly side or rear ground wheel is employed to provide power to the metering unit through power transmission system. To attain a firm grip of the ground wheel over the soil during operation, front ground wheel have been introduced (Fig. 2). Ground wheel having dia. 457 mm was fabricated of MS flat 76 mm × 9.5 mm. Eight spikes were made of MS round having dia. 12.7 mm to connect the hub to the rim of wheel. Pegs of MS round of dia. 12.7 mm have been provided on the outer periphery of the rim, just to address the problem of slippage. Ground wheel has been mounted to the main frame with the help of U-shaped wheel holder that is made of MS channel 64 mm × 32 mm × 5 mm. U-shaped wheel holder is mounted through a centrally pivoted system to follow the contour of the soil. Wheel hub of dia. 70 mm and width 64 mm has been made of mild steel and supported with an axel of dia. 30mm through a set of ball bearings. A sprocket having dia. 76 mm has been provided at the extended end of the hub to transfer the power from ground wheel to power transmission system.

Fig. 2. Ground wheel

Ridging Unit

Three ridging units were fabricated and mounted with the main frame with the help of temporary fasteners (Fig-1). The ridgers were designed to meet the requirement of the ridge configuration for conventional planting pattern. The shank of the ridger was made of mild steel having size 76 mm × 19 mm and ridger wings were fabricated with MS plate of 6.35mm thickness. A v-shaped cutting edge has been provided at front face of each ridger. The cutting edge has been designed in such a way to facilitate the penetration of in ridger into the soil. A shovel share has also been provided just to offer a cutting action in front face of the ridger. The ridger wings are provided with hinges and struts to accommodate different row spacing (Fig-3). The ridging unit, when engaged to the soil, the loose soil is pushed and lifted upwards and inverted on the both sides to form a ridge-furrow by the curvature of the wings.

Fig. 3. Ridger wings with hinges and sturts

The penetration angle of the share of ridger was determined by the following equation as described by Klenin et al., (1985).

$$\Psi = 90 - (\alpha + \Phi)$$

Where:

α = Penetration angle of share
Φ = Soil internal friction angle

By taking clearance angle (ε) and angle of taper of the share (τ) into consideration, the angle of penetration (α) was:,

$$\alpha = \tau + \varepsilon$$

Where:

α = Penetration angle of share
τ = Angle of taper of the share
ε = Rear cutting angle or clearance angle

The ridger was designed with taper angle of 16^{o} and clearance angle (ε) of 11^{o}.

Hence angle of penetration (α) was worked out as,

$$\alpha = \tau + \varepsilon$$
$$\alpha = 16 + 11$$
$$\alpha = 26^{o}$$

As the wings of ridger were provided with hinges and struts for the adjustments of the wings to change the row spacing, wing setting angle (θ) was ranged between 33 - 55^{o} to the direction of travel and the selected range was in line with the angle range 35 - 50^{o} as specified in RNAM 1991 test code (3).

Power transmission system

Seeding and fertilizer units were operated with the help of power transmission system; Both the units were powered by the ground wheel through chain-sprocket and shaft mechanism as shown below. On the hub of ground wheel a sprocket having 14 teeth was mounted and a chain No. 40 was used to transmit the power from ground wheel to main shaft. Main shaft of mild steel having dia. 25.4 mm was used to transmit the power to another sprocket having 19 teeth and dia. 101mm.

Ground Wheel (SP-14 Teeth) → Main Shaft (SP-1 19 Teeth)
↓
Main Shaft (SP-2 24 Teeth) → Fertilizer Unit Shaft (SP-1 24 Teeth)
↓
Fertilize Unit Shaft (SP-2 18 Teeth) → Seed Box Shaft (SP-45 Teeth)

The main shaft also provided concentric motion to the both, the ground wheel and the chain-sprocket unit. From main shaft, power was transmitted to the fertilizer unit through another set of chain-sprocket having 24 teeth and dia. 101mm. A shaft of mild steel having dia. 30 mm was arranged to operate the seeding unit and power was transmitted from the fertilizer unit to the shaft of seeding unit. A set of bevel gears having dia. 67mm and teeth 20 Nos. have been provided for power transmission at 90^o from shaft to seed plate (Fig. 4).

Fig. 4. Power transmission systems

Seeding unit

In order to ensure single seed distribution inclined disc type seed metering unit has been provided. Star wheel aluminum plate of thickness 5 mm and dia. 305 mm having 24 seed groove at its periphery have been provided to transfer the seed at proper interval (Fig. 5). A central pivot system has been developed to the both seeding units for adjustment the angel of inclination (Fig. 6).

Fig. 5. Seed metering unit

Fig. 6. Central pivot system with seed plate drive mechanism

Two seed box with the capacity of 4 kg each have been developed. These seed box are made of MS plate 3 mm thickness, where a base plate having thickness 13 mm has been provided to accommodate the seed plate. Seed plate has been centrally mounted to axle of bevel gear with the help of a set of ball bearings. A flexible seed deflector has been arranged in each seed box to push the seed toward the seed tube. To change the inter seed distance (102 mm, 152 mm and 203 mm) provision has been made to change the speed of seed plate.

Furrow opener

Seed placement at proper depth is of great importance optimum emergence. A pair of coulter type furrow opener having dia. 229 mm and thickness 3 mm is mounted to the shank of MS Flat 8 mm thickness and 48 mm width, with the help of bearings. The shank is attached with the main frame with the help of adjustable depth control system. Set of coulters were so arranged to attain a v-shape groove on the top of ridge to receive the seed. This type of furrow opener displace very small amount of soil when making the furrow (Fig. 7).

Fig. 7. Furrow opener with seed drop chute

Ridge Shaper

Ridge configuration for maize planting is as necessary as the planting technique. A well refined and compacted ridge provides better environment for seed germination. To provide following specifications to the ridge, a ridge shaper has been developed and mounted behind the ridging system.

Ridge height	=	203 mm
Ridge top width	=	152 mm
Ridge bottom width	=	598 mm
Furrow top width	=	521 mm
Furrow bottom width	=	229 mm

A MS pipe having dia. 127 mm was employed and a set of cone shaped cylinders made of MS sheet 14SWG of dia.534 mm were pulled over the pipe. The pipe was mounted with the main frame with help of two links of mild steel having 51mm width and 17 mm thickness. At the both ends of the pipe, side plates are welded to the axle that is supported by a set of bearings having No. 6207 for free rotation of the whole unit. A provision has been made to slide the conical cylinder over the pipe to attain variable ridge configuration. The whole unit of ridge shaper is spring loaded to follow the contour of the ridge formed by the ridger (Fig-8).

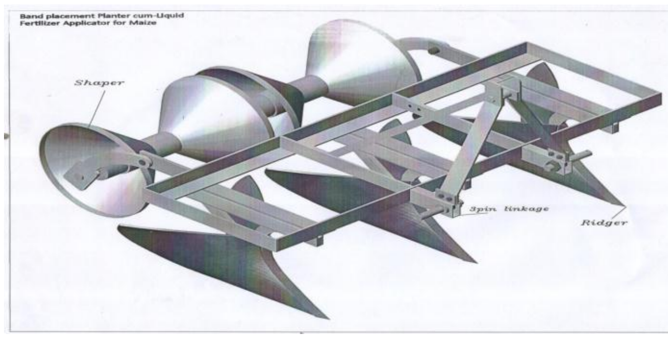

Fig. 8. Ridge shaper with ridgers and main frame

Liquid fertilizer applicator

Phosphoric acid (Agriculture grade) was used in place the DAP fertilizer with the objectives to improve P use efficiency while saving the losses of precious P source usually linked to granular P fertilizer on application to alkaline soils. However, application of controlled quantity of phosphoric acid at a proper depth is utmost important for achieving higher efficiency of the fluid fertilizer. A stainless steel storage tank of capacity 20 liters has been mounted to the main frame, at 1400 mm height. The main storage tank is made of stainless sheet of 16 SWG and a steel ball type flow control valve has been attached at the outlet of the main tank.

Fig. 8. Liquid fertilizer application system with double reservoir

To ensure gravity flow, an orifice system has been developed and to address the discharge variation, a double reservoir of stainless pipe having dia. 25 mm, has been introduced. Air vents at the both ends of second reservoir have been provided to release the entrapped air from second reservoir. The air vents are connected to the main reservoir to encounter any possible splash due to entrapped air in the second reservoir. A set of orifice of dia. 3 mm each, has been provided to the second reservoir to apply phosphoric acid to soil at desired point and in required quantity. Transparent tubes of dia. 8 mm have been attached to each orifice of discharge capacity of 4 liters/min/orifice. A set of drop pipe has been developed and mounted to the furrow opener adjacent to seed chute. Shank of the furrow opener has been mounted to main frame to transfer the draft to the three pin linkage system. To adjust the depth of liquid placement, a shank of MS flat 8 mm × 48 mm, with a series of holes for variable mountings has been provided.

Granular Fertilizer Applicator

In addition to liquid fertilizer applicator, a granular fertilizer applicator has also been developed and mounted to the main frame. Its fertilizer box is made of GI sheet 18 SWG with capacity of 25 Kg. Fluted wheel type fertilizer distribution system has been provided. A metering mechanism has also been arranged to adjust the rate of fertilizer application. Fluted wheels are powered by a central shaft having dia. 21 mm, through chain-sprocket power transmission system. Transparent plastic tubes are attached to the fertilizer distribution system to convey the fertilizer to the furrow opener for its placement in the soil. Granular and liquid fertilizers are placed through the same furrow openers but by different chutes.

LABORATORY TESTING

Sequential arrangement of all the units formed a compact, versatile, low weight and low price Maize Planter-cum Liquid Fertilizer Applicator capable of simultaneous sowing of seed on ridges and liquid fertilizer application in band. In order to place the liquid acid, granular fertilizer and seed into the soil in desired quantity, metering system was designed and developed for trouble free operation. To evaluate the metering systems, all the three units were tested in laboratory. For this purpose a test bench with variable drive electric motor was used.

Testing of seeding unit and its metering system

To maintain inter-seed distance, role of seed metering system is very important. Seed distribution plate having dia. 305 mm and 24 seed groves, is primarily linked with the ground wheel through power transmission system. To place the seed at proper interval 152 mm and 229 mm, provision in power transmission system has been made to adjust the inter seed distance.

Dia. of ground wheel (D)	=	457 mm
Distance travelled in one revolution	=	πDN
	=	22/7 × 457 mm × 1
	=	1436 mm
Distance travelled by ground wheel in 10 revolution	=	14356 mm
Nos of seed grooves on the periphery of seed plate	=	24
Nos of revolutions of seed plate in 14356 mm travel		= 3.92
Nos of seed dropped in 3.92 turns of seed plate	=	24 × 3.92 = 94
Seed to seed distance	=	14356/94
	=	152.7 mm (6 inch)
Dia. of seed plate (d)	=	305 mm
Circumference of seed plate	=	πd
	=	22/7×305
	=	959 mm

In order to place the seed at 229 mm distance, following sprocket sequence has been arranged. Only SP-2 at main shaft and SP-1 at seed box shaft has been changed to reduce the relative speed of the seed plate.

Ground Wheel (SP-14 Teeth)	→	Main Shaft (SP-1 19 Teeth)				
		↓				
		Main Shaft (SP-2 18 Teeth)	→	Fertilizer Unit Shaft (SP-1 24 Teeth)		
				↓		
				Fertilize Unit Shaft (SP-2 18 Teeth)	→	Seed Box Shaft (SP-1 38 Teeth)

A variable drive motor was used at test bench to drive the ground wheel at 3.5 km/hr speed that is optimal speed for field operation. The planter was hanged over the test bench and the ground wheel of the planter was brought in contact to drive wheel of the test bench. Maize seed was placed in the seed boxes. Grease was applied at the surface of flat belt of the test bench. Electric motor of the test bench was switched on and seed load on the seed plate was attained. Travel time of marked point at flat belt of known length was noted and the motor was stopped.

After laboratory testing it was concluded that inter seed distance fluctuates from 120 mm to 190 mm and this was probably due to the drag force of seed tube. From the close observance of seed metering system, it is crystal clear that seed pockets delivered the seeds in sequential order and fluctuation in inter-seed distance is only due to friction offered by the inner surface the seed tube. In order to study the missing seeds, planter was disconnected from the test bench and ground wheel was operated as for field speed and seeds delivered by each unit of seed metering device were counted. It was observed that missing seed percentage was 2 percent.

To test the gravity flow system of the planter, double reservoir system was introduced to encounter the discharge variation due to change in hydraulic head within the main reservoir. A set of orifice having dia. 3 mm was employed to optimize the discharge rate. From testing of the liquid fertilizer application system, 4 lit/min discharge rate was observed. Water is used as a carrier for phosphoric acid. For applying P_2O_5 at recommended rate, phosphoric acid (75-85 % purity) was thoroughly mixed with water in a ratio of 10.8 kg acid/16.2 lit H_2O and this solution is applied through the system at a rate of 4 liters/min when the system was drived as of normal speed of sowing (about 200 ft per min or 3.5 km/ha). A calculated quantity of phosphoric acid is mixed with the water to accommodate the discharge rate in relation with P_2O_5 application to the soil. A cut off valve was provided to on/off the flow of liquid fertilizer.

RECOMMENDATIONS

1. Penetration angle (α) of share should be 26^o and wing setting angle (θ) should be ranged between 33-35^o to the direction of travel for proper ridge configuration and inter-row distance.
2. Flow control valve should be at off position while filling the main reservoir with liquid fertilizer and open it just before the tractor operation in the field.
3. Air vents of the second reservoir must be opened at all the time of operation to avoid the formation of air duckets for uniform flow through the liquid distribution system.
4. Try to adjust the penetration angle of ridger, the Top-link of tractor be adjusted.
5. Any kind of blockage in the seed transfer tube should not be acceptable.
6. Planter calibration is strongly recommended before the maize sowing season.

It is also advised to make sure to use discharge control orifice of recommended size or otherwise liquid fertilizer distribution system should be calibrated with the change of orifice size for recommended dose application.

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Muhammad Akhtar	**:**	**Provided services for liquid fertilizer application rates and other allied literature review, helped in overall testing phase of the planter**
Qurban Ahmad	**:**	**Supervised overall research work and shared technical information regarding seed placement.**
Shahzad Ahmad	**:**	**Contributed in fabrication work of planter and assisted in literature review**