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Research article

Development of tractor operated front mounted grass seed harvester

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Abstract

In order to increase the productivity of grasslands and rangelands, grass seed collection from large fields is required. Manual grass seed collection is a labor and time consuming operation. A tractor operated grass seed harvester was developed keeping in view the requirements of common grasses used as feed material in Indian context. This grass seed harvester was made using nylon brushes arranged in specific fashion on a rotating cylinder and a winding reel in front of rotating cylinder to collect seed from the grasses standing in the fields where tractor can operate. The specific features of this machine were variable speed of rotating cylinder brush, special arrangement of brushes on the cylinder to carry the detached seed into the seed box, variable height of operation and front mounting of the machine on tractor. This machine was tested for seed collection in *Pennisetum pedicellatum* (Dinanath grass) and *Cenchrus cilliaris* (Anjan grass). Seed collection capacity of the machine was 4.24 to 7.12 kg/h in Dinanath grass during 2nd operation and 2.10 to 3.56 kg/h in Anjan grass at the full maturity in two passes of the machine in to and fro direction. The field capacity of seed collection operations ranged from 0.21 to 0.47 ha/h.

Keywords: Grasses, Harvester, Seed collection, Seeds, Tractor operated

Introduction

Agriculture is the main occupation in the country that gives livelihood and profession to more than 70% of the population in India (Anonymous, 2018). Livestock rearing is an integral part of agriculture in various farming systems. India is the largest milk producing country in the world with 187.7 million tonnes of milk production in 2018-19 (Anonymous, 2020). The demand for green and dry fodder in India is expected to increase to 1170 and 650 m tonnes whereas availability is expected to be at 411.3 and 488 m tonnes in 2025, respectively, depicting a deficit of about 64.9% green fodder and 24.9% dry fodder (Anonymous, 2011). The sale of green fodder through retail outlets is a common practice. Cultivation of perennial grasses such as Napier and Napier × Bajra (*Pennisetum*) hybrid is coming up in a considerable way.The area cultivated for fodder amounts to 4% of the total cultivable area, being about 8.3 m ha. Forage crops in general and range grasses and legumes in particular are shy seed producers. In forages, availability of quality seed is only 25-30% in cultivated fodder and less than 10% in range grasses and legumes (Anonymous, 2015). Prices paid for seeds of native plants vary from Rs.5000 to 6500 per kg due to excessive use of manual labour in collection and defluffing of seed. Manual seed collection involves picking of grass seeds manually. Hand picking is full of drudgery and seed yields are low in this method. A 'U' shape fork type device is used to detach the grass seed from the plant and a bag hanging with the neck of worker is used for storing detached seed while collection. Using this manual device, an area of 0.05-0.08 ha/h can be covered for collection of grass seeds.

Many methods and machines are used to harvest grass seed according to agro-climatic region, type of crop and its maturity status. Jorgensenet *et al.* (2004) developed hand held engine powered seed stripper using powered brushes or flail strippers to collect the seed which is filled in a bag attached to it. Briggs (2001) developed utility vehicle (Jeep) mounted grass seed harvester that uses brush or solid steel beaters of approximately 200 mm diameter to collect the seed in a box attached behind it. Grass seed harvesters using brush as seed detaching element

were developed to harvest light and chaffy seeds. A brush that rotated upward at the leading edge strikes the matured seeds, detaches it from the plant and the airflow produced by the shroud-covered brush gathers seed heads into the flailing brush and carries the seed to the hopper. A metal shroud over the brush creates a cross-flow fan action that generates sufficient air velocity to gather seed heads into the flailing brush. Brushing units having width of 1.2 to 3.6 m were used in these types of grass seed harvesters. Cole and Waters (1997) developed pull type grass seed harvester attached to tractor or utility vehicle in which rotating mechanism is operated by the power given by hydraulic circuit from these vehicles.The detached seed was carried into a hopper through the airflow generated by the brush.

Conventional grain combines are also used for harvesting and threshing grass seed in a single operation. These self-propelled combines designed for major grain crops were adjusted to harvest many types of grass seed. Some grass species are cut first with a cutter bar to aid in field drying. A pick-up mechanism mounted on the combine's header is then used to gather the crop into the combine. Harvesting efficiencies, *i.e.,* seed harvested compared with that available, ranged between 28% to 73% (Cole and Waters, 1997) and seem comparable with those quoted elsewhere (Scholz, 1995). Hamani *et al.* (2018) observed that harvest period has significant effect on seed germination. Large grass production farms and fallow lands needed a machine that is suitable for harvesting seeds timely. Sharma (2015) revealed that growing of cluster bean or moth bean with any multi-purpose tree species *viz*., khejri, ardu and rohida plantation holds promise to provide higher and economical grain productivity with improved fertility status of soil under agrisilviculture system in arid tropics of Rajasthan. So a tractor operated machinery can be used well in this system also. Harvesting of fodder at frequent intervals (*Desmanthus virgatus* at 30 days interval) and its seeds was advocated for production of protein rich fodder with higher nutritive value (Mynavathi *et al.,* 2021) for which operation of machinery will be suitable.The feed consumption of a dairy cow requires substitution of concentrate feeds/ cereal grains by high quality forages to produce more edible milk energy or protein (Mahanta *et al*., 2020) supports the requirement of more grass seed and thus a suitable machine requirement for grass seed production. Such type of machine may be of high use to dairy cooperatives in Indian as they are producing around 4500 metric ton seeds annually through 17 fodder seed processing plants in different states (Choudhary *et al*., 2022). Chaffy and light weight grass seed like that of Cenchrus grasses have low seed yield, while high demand (Meena and Nagar, 2019). In such cases a machine is useful to collect the grass seeds. Therefore, a tractor operated grass seed harvester was developed for harvesting grasses like Dinanath and Cenchrus.

Materials and Methods

Morphological properties of grasses: The morphological properties of selected grasses used as feed material were studied (Trivedi, 2010) for development of suitable grass seed harvester. Ranking was assigned to them according to their utility in feeding and need to harvest by grass seed harvester. *Pennisetum pedicellatum* (Dinanath) grass was given as rank 1 for collection of grass seed using tractor operated grass seed harvester.

Design of the machine: Tractor operated grass seed harvester was made to fit in front of tractor so that it collects the seed from the standing crop before tractor tyres run on to it.The height of operation and rotational speed of seed collection cylinder were controlled by hydraulic levers near the driver's seat. A rotary cylinder having brushes arranged in a definite fashion was made as seed collecting element from the grass. The brushes were arranged in helical manner on the rotating cylinder. A winding reel was made in front of the rotating cylinder to press the crop against the brush to increase the seed detachment. The height of operation of seed detaching cylinder was variable so that it is used in grass crops of different heights. The seed detached by the rotary cylinder was carried by the flow of the wind to the seed collection box behind the rotary cylinder. The designs were prepared in Computer Aided Design (CAD) software (Fig 1).

Prototype grass seed harvester was developed with grass seed collection mechanism made of nylon bristle arranged in 20 mm thickness up to running length of the cylinder. The brush had a total height of 150 mm and it was supported on flexible poly support of 50 mm with protrusion of 100 mm. The base was made of flexible poly material to allow fixing in spiral shape. These flexible poly brushes were fixed in spiral fashion on 300 mm diameter rotary cylinder. The drum was able to be rotated in both upward and

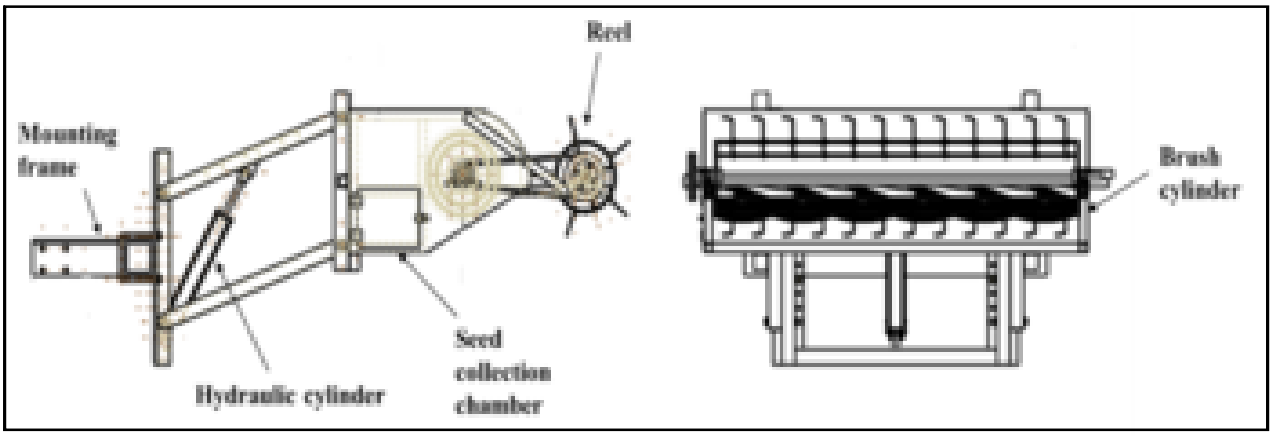

Fig 1. Plan and elevation of tractor operated grass seed harvester

downward directions. The bristles were arranged in a spiral fashion so that seed detached from plant is carried away smoothly to the collection chamber in the wind tunnels created by rotary cylinder and brush. This rotary cylinder unit was able to be lifted and lowered while the operation in the field. Rotary speed of the drum was variable in the range of 50 to 400 rpm. The variable speed of rotor allowed collection of different seed material that requires different detaching force. This machine was able to harvest the seed from 300 to 1500 mm in height. The whole machine was fixed on a frame and it was mounted on the front of the tractor, and it operated under certain specifications (Table 1).

Operation of machine: Tractor operated grass seed harvester was operated in standing grass crops, Dinanath and Cenchrus. Due to non-synchronous maturity of grass seeds in Dinanath, seed collection was done two times- at the time when seed started maturing and 20 to 22 days after first operation. In each operation, the machine was operated twice on the same path in to and fro direction. In other grasses, the seed collection was done one time at the time of full maturity. The seed collection was done at different rotating drum speeds of the brush, reel speeds and forward speeds of the machine. Before operation, the seed available in unit area was measured in weight. Seed left in the crop after operation of the machine

Table 1. Specifications of tractor operated grass seed harvester

Item	Attribute
Power source	Tractor, 25.8 kW
Position of the seed collection mechanism	In front of tractor
Controls of the harvesting mechanism	From driver's seat
Seed harvesting mechanism	Rotating cylinder and brush
Rotary motion of brush	Hydraulically controlled from tractor seat
Hydraulic cylinder (double acting type)	Pressure: 175 bar, Stroke: 350 mm
Hydraulic motor	Displacement: 20 cc, torque: 25 N.m
Counter balance valve	Flow: 30 lpm, pressure: 315 bar
Flow control valve	Flow capacity: 8 lit/min, pressure: 140 bar
Type of brush	Nylon bristle 75 micron thickness, arranged in two rows to form continuous brush
Direction of rotary motion	Upward and downward
Rotary speed of cylinder containing brushes	Variable from 50 to 400 rpm
Height of operation	Variable through hydraulic controls from 300-1500 mm
Swath of operation	1800 mm

was measured from the similar area and thus seed collected from unit area was taken at a particular rotational speed and forward speed of the machine. This determined seed collection efficiency of the machine. Trash coming in the box was also measured in weight and it was calculated as the percentage of the seed weight collected in a particular operation. Seed collection capacity of the machine was determined by weighing the seed collected in the box in 5 minutes of operation at a particular rotational speed of seed collection cylinder and forward speed of the machine. These parameters were seen against the reel index of the seed harvesting machine. Seed collected from unit area, matured seed left in crop in unit area, seed collection efficiency (weight wise), trash coming in the box (weight wise) was seen in respect of the reel index. Reel index is defined as

$$i = r \cdot \omega / v \quad \text{..... (1)}$$

where, r = radius of reel,m

ω = rotational speed of the reel, rad/s

and

υ= forward speed of the machine, m/s

During the operation, the engine speed of tractor was set at 1800 rpm with variation of ±3% and harvesting cylinder brush was operated at different rotational speeds of 100, 150 and 200 rpm. The variation in rotational speed of harvesting cylinder was ±6% while in operation. The radius of the winding reel including brushes was 225 mm.The machine was operated at three forward speeds of the tractor being as 2.07, 3.11 and 4.56 km/h in Low 1, Low 2 and Low 3 gears, respectively. The harvesting brush cylinder was operated in upward rotational direction such that the reel was pressing the crop against the brush while in operation. Seed collected in the box in 5 minutes of operation, trash collected in the box in 5 minutes of operation, seed collection capacity in the box, trash coming in the box, (weight wise) and effective field capacity of the machine was observed.

Results and Discussion

Dinanath grass seed collection: Tractor operated grass seed harvester was operated for the first time in Dinanath grass when the seed started maturing (Fig 2). The height of operation was kept at 600 mm. The height of operation was taken as the height of the central point of the harvesting brush cylinder from the ground level. Engine speed of tractor was set at 1800 rpm and operation was conducted on 100, 150 and 200 rpm of harvesting brush cylinder as narrated in methodology. In this state of the crop, seed bearing was less and seed collection was also less by the machine. The second operation of grass seed harvester was done after 20 to 22 days of first operation of seed collection. At this time the seed bearing was profuse in the crop. The relation in forward speed of operation (km/h), speed of rotation of brush (rpm), speed of rotation of winding reel (rpm), reel index, seed collected from unit area (g), matured seed left in crop in unit area (g), collection efficiency (%)[weight wise], seed collected in the box in 5 minutes of operation (kg), trash collected in the box in 5 minutes of operation (kg), seed collection capacity in the box (kg/h), trash coming in the box (%)[weight wise] and effective field capacity (ha/h) of the grass seed harvester in 2nd operation in Dinanath grass were recorded (Table 2).

Fig 2. Operation of tractor operated grass seed harvester in Dinanath grass

The relation between reel index and seed collection from unit area, seed left in crop in unit area and trash collected during 2nd operation (weight wise) was recorded (Fig 3). In this operation, the seed collected per unit area from the machine increased slightly with reel index and seed left in the crop in unit area decreased with reel index. This might be due to the reason that seed came to fully matured state and it was being easily collected by rotating brush cylinder and winding reel motion. In this case trash coming was also slightly increasing with reel index as the dried leafy part was coming in the collection box with the seed. As the reel index was increasing, the seed collection from unit area was decreasing and seed left in the crop was increasing exponentially and the trash coming in the seed collection box was decreasing slightly. In this case it was beneficial to operate the machine in lower reel index ranged from 1 to 2. This indicated that the tractor was operating in 2nd low gear

Table 2. Reel index of grass seed harvester versus operational parameters of the machine during 2nd seed collection operation in Dinanath grass

Forward speed of operation of tractor (km/h)	Rotational speed of harvesting brush cylinder (rpm)	Rotational speed of winding reel (rpm)	Reel index	Seed collected from unit area of 1 m^2 (g)	Matured seed left after operation in unit area of 1 m^2 (g)	Collection efficiency (%, weight wise)	Seed collected in the box in 5 minutes of operation (kg)	Trash collected in the box in 5 minutes (kg)	Seed collection capacity in the box (kg/h)	Trash coming in the box (%, weight wise)	Effective field capacity (ha/h)
2.07	100	50	2.05	21.7	10.2	68	0.3854	0.0042	4.625	1.1	0.21
2.07	150	75	3.07	23.4	21.6	52	0.4364	0.0052	5.237	1.2	0.24
2.07	200	100	4.10	22.1	27	45	0.3529	0.0113	4.235	3.2	0.24
3.11	100	50	1.36	27.8	8.8	76	0.5423	0.0007	6.507	0.12	0.32
3.11	150	75	2.05	31.3	8.8	78	0.6104	0.0067	7.325	1.1	0.35
3.11	200	100	2.73	29.7	4.8	86	0.5937	0.0152	7.124	2.56	0.33
4.56	100	50	0.93	32.5	17.5	65	0.4725	0.0184	5.67	3.9	0.39
4.56	150	75	1.40	29.4	18.8	61	0.5427	0.0293	6.512	5.4	0.38
4.56	200	100	1.86	27.5	11.2	71	0.5192	0.0327	6.23	6.3	0.41

(medium speed), it was beneficial to operate the cylinder at 150 rpm and when the tractor was operating in 3rd Low gear, it was beneficial to operate the machine on 100 rpm. This was because seed detachment was more effective in a particular range of peripheral linear speed which was combination of both rotational and forward speed. Beyond this trash content coming in the seed was higher that needs to be avoided. The relation of seed collection capacity and effective field capacity in respect of forward speed of the machine was recorded which showed that both were increasing with forward speed (Fig 4).

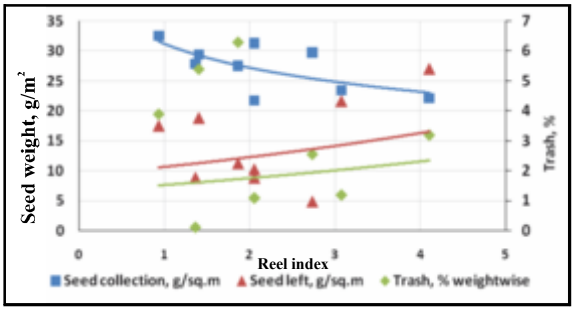

Fig 3. Relation between reel index and seed collected from unit rea, seed left in the crop in unit area and trash coming in seed collection box in Dinanath grass

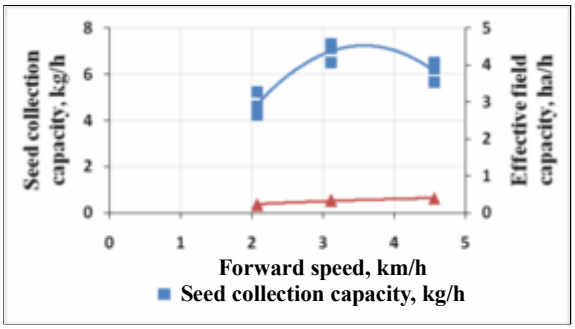

Fig 4. Relation between forward speed of operation, seed collection capacity of machine and effective field capacity in Dinanath grass

ANOVA of seed collection from unit area and seed left in the crop in unit area in first operation of the machine in Dinanath grass was recorded (Table 3). It indicated that both of these parameters were non-significant with reel index. Reel index took care of both forward speed and rotational speed together. Seed collection was independent of these parameters while operation of the machine. However, it depended on the state of maturity of the seed and ease with which it was detached from the plant.

Table 3. ANOVA of seed collection, seed left and trash coming in collection box

Groups	Count	Sum	Average	Variance		
Reel index	9	19.55	2.172222	0.969994		
Seed collection (g/m^2)	9	245.4	27.26667	15.8875		
Seed left (g/m^2)	9	128.7	14.3	52.78		
Trash (%, weight wise)	9	24.88	2.764444	4.493578		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit.**
Between groups	3777.136	3	1259.045	67.93618	5.71E-14	2.90112
Within groups	593.0486	32	18.53277			
Total	4370.185	35				

Cenchrus grass seed collection: Grass seed collection operation in Cenchrus grass was done one time in the season when seeds were profuse in the crop and were at full maturity stage. While collection of seed, the machine was operated two times in to and fro direction on each path. The height of operation was kept as 700 mm. Engine speed of tractor was set at 1800 rpm and operation was conducted on 100, 150, 200 and 250 rpm of harvesting brush cylinder. The relation among the forward speed of operation(km/h), speed of rotation of brush (rpm), speed of rotation of winding reel (rpm), reel index, seed collected from unit area (g), matured seed left in crop in unit area (g), collection efficiency (%) (weight wise), seed collected in the box in 5 minutes of operation (kg), trash collected in the box in 5 minutes of operation (kg), seed collection capacity in the box (kg/h), trash coming in the box (%) (weight wise) and effective field capacity (ha/h) of the grass seed harvester operation in Cenchrus grass were also recorded (Table 4).

The relation between reel index and seed collected from unit rea, seed left in the crop in unit area and trash coming in seed collection box during seed collection in Cenchrus grass was also recorded (Fig 5). It was seen that seed collection per unit area, seed left per unit area and trash coming in the seed box were slightly increasing with increase in reel index. Trash coming in the seed was removed manually and seed was stored for few months as highest germination (up to 48%) was recorded in spikelets of *Cenchrus ciliaris* and *C. setigerus* after 9 months and up to 18 months (Nagar and Meena, 2022). So the machine operation was preferable in the range of reel index 2 to 3 where collection capacity was higher and trashes coming were lower.

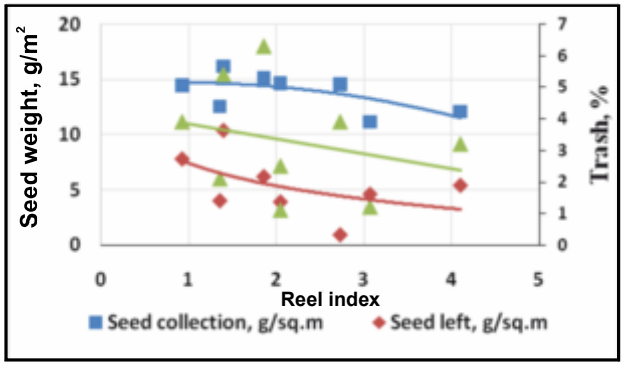

Fig 5. Relation among reel index and seed collected from unit area, seed left in the crop in unit area and trash coming in seed collection box during seed collection in Cenchrus grass

Crop damage: Tractor operated grass seed harvester was attached in front of tractor and for seed collection with this machine, whole tractor ran over the standing grass crop. The plants/ crop coming beneath the tires laid to the ground in a single pass of operation and laid to 30 to 50 degree from ground. The brush cylinder took the seeds from these plants in first pass. While second pass of operation direction, the brush cylinder tried to lift the crop on the same path and seed collection was done in this process. Crop coming beneath tractor tires laid to the ground and seed collection was much less from that path. This led to seed collection loss from the crop that came beneath the tires.

Stationary operation: In case when the crop was harvested and kept for drying, this machine could be operated, while the tractor is in standing condition. This was called as stationary operation of grass seed harvester. In this case the harvesting brush cylinder was given rotary motion and the crop was fed manually to the cylinder so that it could touch the

rotating brush and the stocks of the crop remained in hands of operator. In case of Dinanath grass seed the harvesting capacity was from 6 to 7 kg per hour when two men used to feed the crop against the rotating harvesting cylinder. Due to manual feeding of the crop against the cylinder the seed shattering was to the extent of 600 to 700 g per hour that did not go into the seed collection box and shattered outside. This was collected manually from the ground.

Economics of operation: Considering a small tractor of cost Rs. 4,50,000 and initial cost of grass seed harvester as Rs.1,50,000, the cost of operation per hour was obtained as Rs.496. The cost of operation of grass seed harvester was Rs. 1503 to Rs. 2255 per hectare dependending upon the actual field capacity obtained with lesser cost at higher forward speed of operation. This indicated that it was beneficial to operate the machine at higher forward speed that expected to give higher field capacity and low cost of operation.

Conclusion

A novel tractor operated grass seed harvester was developed that had the seed collection capacity of 4.24 to 7.12 and 2.1 to 3.56 kg/h for Dinanath and Anjan grass, respectively at the full ripening stage of the crop. The field capacity of machine varied from 0.21 to 0.47 ha/h depending upon the forward speed of operation. The height of operation of grass seed harvester was variable from 300 to 1500 mm above ground level and rotary speed of seed collection brush cylinder was variable from 50 to 400 rpm. The height of operation and variable speed of rotary brush cylinder addressed the collection of seeds from different grass crops. The cost of operation of tractor operated grass seed harvester varied from Rs.1503 to Rs.2255 per hectare, with lesser costs coming at higher forwards speed of operation in 3rd low gear. The seed collection capacity of machine was better (5.6 to 7.3 kg/h) at low forward speed of 3.11 km/h with 150 rpm rotational speed of the drum and at higher (4.56 km/h) forward speed with 100 rpm rotational speed of the drum. In this range of operation trash content coming with seed was also less (1.1 to 3.9%) in case of Dinanath grass.

Table 4. Reel index of the machine versus operational parameters during seed collection operation in Cenchrus grass

Forward speed of operation (km/h)	Speed of upward rotation of brush (rpm)	Rotational speed of winding reel (rpm)	Reel index	Seed collected from unit area of 1 m^2 (g)	Matured seed left in crop in unit area 1 m^2 (g)	Collection efficiency (%, weight wise)	Seed collected in the box in 5 minutes of operation (kg)	Trash collected in the box in 5 minutes (kg)	Seed collection capacity in the box (kg/h)	Trash coming in the box (%, weight wise)	Effective field capacity (ha/h)
2.07	100	50	2.05	10.8	5.1	68	0.1752	0.0019	2.102	1.1	0.22
2.07	150	75	3.07	11.2	4.6	71	0.1934	0.0023	2.321	1.2	0.23
2.07	200	100	4.10	12.1	5.4	69	0.2043	0.0065	2.451	3.2	0.24
3.11	100	50	1.36	12.6	4	76	0.2678	0.0056	3.213	2.1	0.3
3.11	150	75	2.05	14.7	3.9	79	0.288	0.0072	3.456	2.5	0.32
3.11	200	100	2.73	14.6	0.9	94	0.2706	0.0106	3.247	3.9	0.33
4.56	100	50	0.93	14.5	7.8	65	0.2713	0.0106	3.256	3.9	0.41
4.56	150	75	1.40	16.2	10.4	61	0.2707	0.0146	3.248	5.4	0.42
4.56	200	100	1.86	15.2	6.2	71	0.297	0.0187	3.564	6.3	0.44

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