Effect of Plant Crushing by Machine Traffic on Re-Generation of Multi-Cut Berseem Fodder

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Abstract

There are many soft stemmed multi-cut fodder crops (berseem, lucerne, stylo) grown in fodder production farms. Harvesting large areas of crop requires operation of heavy machinery in the field where crop is standing. A study was conducted to find out the crushing of plants by machinery and reduction in yield of crop in subsequent harvesting operation. Two types of harvesting machines viz. tractor operated cutter bar type fodder harvester and riding type engine operated fodder harvester were used for harvesting berseem during first three cuts of the crop. Plant crushing by the machinery was studied with number of plants falling in unit area of the path way of machinery. The growth pattern of plant crushed under tires was observed. In berseem field, one square meter area consisted of average 124.8 to 139.3 no. of plants during different cuts, out of which 34.03 to 52.0% plants were crushed by tyres in case of tractor operated harvester. Growth behaviour of crushed plants showed that there was tendency to heal the crushing of plant by tractor tyres. The visual demarcation between the crushed and not crushed plants reduced after four days. The trend of healing continued and after 12 days after operation, there was no difference between the plants that came under tyres and the plants that did not come under tyres. The yield of harvested crop was on par with manually harvested crop during 1st, 2nd and 3rd harvesting operation.

Key words: Harvesting, Mechanical, Fodder, Regeneration, Traffic

Introduction

Cultivated fodder crop harvesting in large fields requires operation of harvesting machinery in the standing crop. The quantity of work increases manifold in case of multi-cut fodder crop. Operation of machinery becomes mandatory in the fields for completion of harvesting in time. Multi-cut fodder crops like berseem, lucerne, stylo, oats are soft and succulent in nature and it was speculated that operation of heavy machinery in the field adversely affects regeneration of crop.

Bailey *et al.* (1996) studied soil stresses under a tractor tyre at various loads and inflation pressures and found that peak soil stresses and bulk density increased with increase in both dynamic load and inflation pressure. Increase in sol stresses suggests that with increase in speed of operation and inflation pressure of tyres, there is higher chance of damage to the soft fodder crops over which tractor runs with harvesting machinery.

Rodriguez *et al.* (2012) studied soil compaction under tyres for harvesting and transporting sugarcane at three inflation pressures (207, 276 and 345 kPa) and six loads ranging from 20 to 60 kN/tyre and found that contact surface between tyres and soil increased with increasing load and decreasing inflation pressure. However, contact pressure presented no defined pattern of variation. Among the different tyres tested (A-block shape tread; B-rib shape tread; C-low lug tread; D-high lug tread), tyre types A and B registered vertical stresses below 250 kPa at highest loads.

Nankali *et al.* (2012) analysed stress arising on tractor tyre soil interaction using symmetric Moony-Rivilin model having 2D finite element method and compared the same with measured field response data available in literature. The maximum soil-tyre pressure of 83.7 kPa was found for 70 kPa inflation pressure and 15 kN axel load which were approximately 30% less than the stress at the tyre contact patch in the field test as reported in the literature. Maximum vertical stress at contact area was 98.6 kPa for 150 kPa inflation pressure and 15 kN axel load.

Results of these studies state that there is considerable stress working on the soil-tyre interface while working in the field conditions. The stresses are further higher when tractor carried an implement for operation increasing the load of the tractor-implement system. When the soft stemmed fodder crop is harvested using tractor operated machinery in the field, the tractor tyres run on the remains of harvested plant. With the stress in the range of 83.7 kPa to 250 kPa arising out of the tyre soil interaction, there was a possibility of crushing of remains of the green succulent harvested plants. The concern of crop grower is that plants remain intact for maintaining the yield of fodder during next harvesting operation. With growing mechanization for harvesting of fodder crops, it becomes necessary to study the effect of stress on the regeneration of plant and yield of fodder crops on subsequent harvesting operation. So, in order to study the crushing of soft fodder crop with tractor tyres and heavy machinery, a study was taken up to find the effect of operation of machinery on the regeneration and yield of multi-cut fodder crop berseem in the central research farm of Indian Grassland and Fodder Research Institute, Jhansi, India.

Materials and Method

Fodder crop berseem was taken in this study since it is soft, succulent and provides multi-cut fodder crop. Two types of harvesting machines used for harvesting were Tractor operated cutter bar harvester and Engine operated riding type reaper.

Tractor operated cutter bar type fodder harvester mounted on three point linkage system harvested the crop and left it into the field without making windrows (**Fig. 1**). It was operated by a 26.1 kW capacity tractor that had tyres of size 315 × 711 mm and weight of 1,300 kg. Inflation pressure maintained in the rear tyres were 110 kPa and front tyres were 207 kPa. Inflation pressure of tyres was checked every time before harvesting of the crop. Fodder reaper had 1.8 m wide cutter bar that operated in the offset of tractor. For starting of harvesting in the field by tractor, headland of 2.0 m width was harvested manually to allow tractor movement without damaging of crop.

Fig. 1 Tractor operated cutter bar type fodder harvester

Fig. 2 Engine operated riding type fodder harvester

Engine operated riding type reaper also had a cutter bar of width 1.2 m for harvesting fodder crop. In this case harvested crop was left in a windrow (**Fig. 2**). This machine had two pneumatic tyres that were powered for motion and a third pneumatic, toed support wheel above which a seat was provided for operator. All the controls for operation of machine were near operator seat. Tyres of size 152 × 406 mm were used with this machine and it had weight of 400 kg. The inflation pressure in powered lugged wheels was maintained at 138 kPa and in the toed wheel it was maintained at 207 kPa. Inflation pressure was checked every time before operating the machine in the field.

The harvested crop in both the cases was collected and heaped on the side of field from where it was loaded in tractor trolley for transportation. In case of tractor operated fodder harvester, the crop from whole field needed raking and gathering, whereas engine operated riding type fodder harvester windrowed the crop and gathering was required from rows only. So, collection of harvested crop and heaping in the side of field in later case had less labour requirement for loading in to the trolley. Harvesting of crop was started five days after irrigation and was continued daily after that. After five days of irrigation, tyres do not sink in the field. Count of plant population was done in unit area. The area for plant population was taken on the path of run of tyres such that it covers the whole width of tyre while movement. Data was recorded up to three consecutive days from starting of harvesting operation. Total numbers of plants in unit area were counted by throwing 1 × 1 m square frame in the field after the tractor had run and tyres have made crushing print on the field. In this unit area, plants pressed by the tyres were counted. Plants having thickness more than 2 mm were considered for counting. Three replications of counting were done in each case. The soil sample was collected for measuring moisture content in the field.

Results and Discussion

Operation of tractor operated machinery and riding type harvester inserted pressure on the ground and on the plants of multi-cut fodder crop that was of multi-cut nature. The machines were operated in the field where crop was standing and crop production unit operations were being continued. So, the pressure applied by the tyres of running machinery on the plants and plant population coming under tyres were studied. After harvesting operation, the growth pattern of crop was studied.

Pressure Beneath Tyres

Maximum pressure beneath tyres was calculated for both tractor operated reaper and engine operated riding type reaper. In case of tractor operated machine, the mass supported by tyres were 1,300 kg of tractor, 300 kg of reaper and 100 kg of driver and fuel and others amounting to a total of 1,700 kg. It was considered that 80% of the weight falls on rear tyres of tractor and 75% of width of tyres was the length of tyre impression on the ground at any given instant. With these facts, maximum pressure beneath each traction tyre of tractor was found to be 89.6 kPa. Whereas, in case of riding type reaper total mass acting on the wheels was 350 kg including that of operator. Here also, it was considered that 80% weight falls on powered tyres and 75% of tyre width was the length of tyre impression on the ground at any given instant. With these figures, maximum pressure beneath each powered tyre of riding type reaper was 90 kPa.

Eventually, both the type of reapers viz. tractor operated and riding type applied near about the same maximum pressure of 89.6 and 90.0 kPa, respectively. So the magnitude of damage to the green plants while operation in the field may be considered to be of the same magnitude. In the harvesting and transportation studies of sugarcane, Rodriguez *et al.* (2012) found that maximum vertical stress occurring below tyre was 250 kPa for two types of tyres, which was much higher than the stress occurring below tyres (90.0 kPa) in case of berseem harvesting. The lower stress in case of fodder harvesting is due to use of light weight machinery compared to that used in sugar cane harvesting.

Table 1 Average plant population, plants crushed with tyres and erect plant population 12 days after harvesting with tractor operated cutter bar type fodder harvester

Day	Plant population Number/m^2	No. of plants crushed	Per cent plant crushed Number /m^2	Erect plant population 12 days after harvesting Number/m^2	Moisture content of field, per cent (d.b.)
1st cut					
Day 1	120	29.3	24.4	127.3	18.4
Day 2	138	36.5	26.4	134.5	14.48
Day 3	134.7	36.3	27	134.3	12.83
Average	130.9	34.03	26	132	15.24
2nd cut					
Day 1	138.3	45	32.5	130	16.76
Day 2	105	35	33.3	133.3	15.31
Day 3	131	47.3	36.1	123	14.85
Average	124.8	42.43	34	128.8	15.64
3rd cut					
Day 1	139	52.7	37.7	142.3	17.88
Day 2	144	55	37.9	130	14.35
Day 3	135	48.3	35.8	142	12.33
Average	139.3	52	37.1	138.1	14.85

Plant Population

Average plant population before harvesting, plants crushed by the tyres, and erect plant population 12 days after harvesting was taken in the field conditions. **Table 1** shows average plant population in the field and plants coming under tyre of tractor operated cutter bar type fodder harvester.

Average of three counting of plant population showed that during 1st cut, plant population per unit area (1 m^2) varied from 120.0 to 144.0 out of which 24.4 to 27.0% plants got crushed by tractor tyres. Crushed plants laid down to earth in moist soil making a thorough impression of the path of run of tyres. Taking average of all the plants, there stood 130.9 plants per square meter out of which 25.9% plants came under tyres. Crushed plant were observed and photographed daily. The crushed plants on the path of tractor got up and stood erect and 12 days after operation the average plant population was 132.0. Plant population observed later was more because during collection of sample of erect population, the unit area where square frame was thrown for sampling was not exactly the same as taken before harvesting. In the broadcasted field of berseem there was high variation in number of plants per unit area from one place to another. During all the days of sample collection, erect plant population 12 days after harvesting was found to be independent of the plant population before harvesting. This stated that the plant that got crushed and fell to soil while operation of tractor tyres stood well and formed good crop canopy for another harvesting, as required in multi-cut fodder crops.

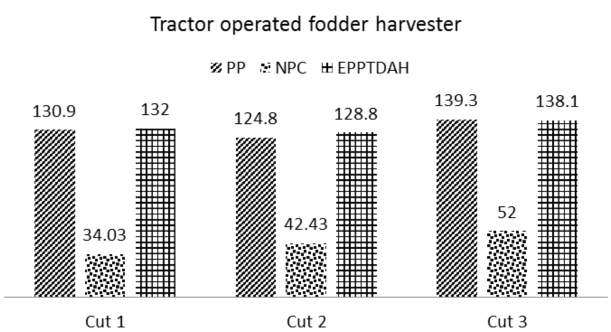
Similarly, in 2nd time harvesting operation, average plant population was 124.8 before harvesting and 34.0% plants came under tyres. Average plant population 12 days after harvesting was 128.8. Whereas, in the third time harvesting operation, average plant population was 139.3 before harvesting and 37.1% plants came under tyres. The average erect population 12 days after harvesting was found as 138.1. The plants crushed by the tyres of riding type fodder harvester are shown in **Table 2**.

In case of harvesting with riding type fodder harvester the same trend continued as with tractor operated fodder harvester. Average plant population in 1st, 2nd and 3rd cut varied from 121.4 to 129.3 before harvesting and 19.3 to 26.2% plants came under tyre. Whereas, plant population 12 days after harvesting was in the range of 133.2 to 138.0. Here also the plant population 12 days after operation was higher in some cases due to sampling place not being exactly the same as before operation and profuse growth of crop after harvesting. However, there was no definite relation of increase or decrease observed in plant population, before and after harvesting operation. This confirmed the results that crushed plants stood well forming good crop canopy for another harvest in case of second machine also i.e. engine operated riding type fodder harvester. The Average plant population, plant population that came under tyre and plant population 12 days after harvesting during 1st, 2nd and 3rd cut with tractor operated fodder harvester and riding type fodder harvester is shown in **Figs. 3** and **4**, respectively.

It was also observed from the data recorded that average plant population crushed by the tractor tyres increased slightly during subsequent operations. This was due to more growth of plants after harvesting operation. This may also be due to counting of plants thicker than 2

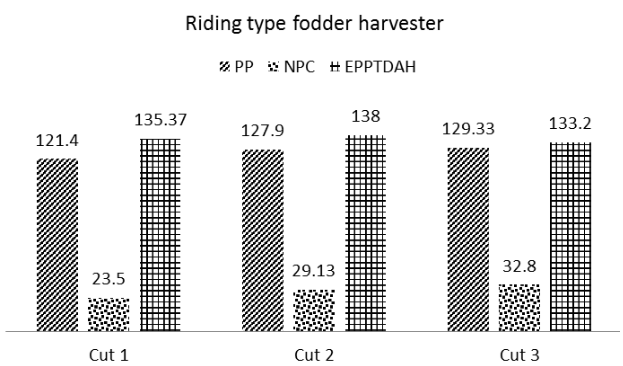
Table 2 Average plant population, plants crushed by tyres and erect plant population 12 days after harvesting with riding type fodder harvester

Operation	Plant population Number /m^2	No. of plants crushed	Per cent plant crushed Number/m^2	Erect plant population 12 days after harvesting Number/m^2	Moisture content of field, per cent (d.b.)
1st cut					
Day1	120	23.3	19.4	127.7	15.52
Day2	120.5	23.5	19.5	146.7	15.25
Day3	123.7	23.7	19.1	131.7	13.64
	121.4	23.5	19.3	135.4	14.8
2nd cut					
Day 1	136.3	27.7	20.3	149.3	15.67
Day 2	126.7	28.7	22.6	132	13.35
Day 3	120.7	31	25.7	132.7	12.11
	127.9	29.13	22.9	138	13.71
3rd cut					
Day 1	143	34	24.2	126.3	17.57
Day 2	111	32.7	30.6	136.3	15.3
Day 3	134	31.7	23.9	137	13.49
	129.3	32.8	26.2	133.2	15.45



PP: Plant population; NPC: Number of plants crushed; EPPTDAH: Erect plant population 12 days after harvesting

Fig. 3 Average plant population, number of plants crushed and erect plant population 12 days after harvesting during 1st, 2nd and 3rd cut with tractor operated harvester



PP: Plant population; NPC: Number of plants crushed; EPPTDAH: Erect plant population 12 days after harvesting

Fig. 4 Average plant population, number of plants crushed and erect plant population 12 days after harvesting during 1st, 2nd and 3rd cut with riding type reaper

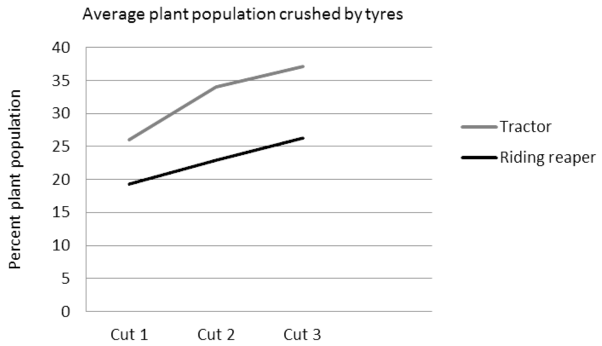


Fig. 5 Average plant population crushed by tyres during different cuts

Table 3 Average fodder yield during different number of cuts

No. of cut	Average fodder yield, q/ha		
	Tractor operated harvester	Riding type reaper	Manual harvesting with sickle
1st	97	101.7	101.7
2nd	210	210	223.3
3rd	226.7	223.3	223.3

mm only that might have grown in subsequent operations. **Fig. 5** shows average plant population crushed by tyres during different cuts.

Growth Behaviour

The growth pattern of the plants crushed by tyres was photographed daily after harvesting operation. It was observed that there was a tendency of healing of the plants crushed by tyres. It was also observed that four days after harvesting, the plants that came under tyre also started growing in the same pattern like other plants. Eight days after harvesting, it was difficult to differentiate between the plants that came under tyres and twelve days after harvesting, there was absolutely no difference among the plants that came under tyres and that did not come under tyres. This resulted in the yield of the crushed plants being equivalent to that of the non-crushed plants. **Table 3** shows average fodder yield from the fields harvested using tractor operated fodder harvester, riding type fodder harvester and manual sickle.

Table 3 shows that yield of fodder was not significantly different when it was harvested manually or using any of the machines taken in this study. This was the trend during all the three i.e. 1^{st}, 2^{nd} and 3^{rd} number of harvesting. So, operation of fodder harvesting machinery can be done without sacrificing the yield due to mechanical crushing.

Conclusions

It was concluded that operation of tractor operated machinery and riding type reapers do not affect the growth of multi-cut soft fodder crop. The plant population that is crushed under tyres grows equally well and stands erect fully 12 days after harvesting. The growth behaviour of crushed and not crushed plants remains the same and the yield has no significant difference up to three number of harvesting operation.

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