Crop lodging and management

By

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Seminar Report

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DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

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DECLARATION

I, Basila Y. (2018-11-027) hereby declare that the seminar report entitled “Crop lodging and management” has been completed by me independently after going through references cited here and I haven’t copied from any of the fellow students or previous seminar reports.

Vellanikkara | Basila Y.
20/01/2020 | 2018-11-027

CERTIFICATE

This is to certify that the seminar report entitled 'Crop lodging and management' has been solely prepared by Basila Y. (2018-11-027), under my guidance and has not been copied from seminar reports of seniors, juniors or fellow students.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1. Introduction

Lodging is one of major constraint leading to tremendous yield reduction in grain crops. Significant progress was made during 1960s by the introduction of high yielding semi-dwarf varieties to reduce lodging risk. These semi dwarf varieties make the plant to response under heavy dose of fertiliser and this was the reason for increased grain yield. Lodging is still a major problem in many countries. It is very difficult to control because it is influenced by many factors. So there is a need to improve lodging resistance to sustain productivity.

Plate 1: Crop lodging in wheat

1.1. Definition and types of lodging

Lodging is defined as the permanent displacement of stem from its upright position. It is common in all cereals and other crops such as rapeseed and sunflower. Cereals generally exhibit two types of lodging, stem lodging and root lodging. Stem lodging is termed as bending or breaking of lower culm internodes and root lodging is termed as when roots fails to uphold tough soil contact or have broken anchorage in the soil. Cereals are prone to the effects of both root and stem lodging. Both types of lodging can occur singly or together, and can reduce growth and yield. Lodging is often not distributed uniformly throughout an affected field but may be scattered over certain section or spots.

Plate 2: Stem lodging in wheat **Plate 3: Root lodging in maize**

2. Causes of crop lodging

Lodging is induced as a result of inadequate standing power of the crop,adverse weather conditions such as heavy rain and strong wind,high levels of nitrogen, high seed rate, excessive soil moisture, use of tall varieties and incidence of pest and diseases.

3. Plant characters associated with lodging

3.1. Culm characters

3.1.1. Culm length

Plants with higher culm length are more susceptible to lodging

3.1.2. Basal internode

Plants with short stem internodes especially in the lower part of the stem are more resistance to lodging than are plant with long stem internodes. Large stem with thick wall resist greater external lodging forces.

3.1.3. Plant height

Tall plants are more susceptible to lodging than short plants

3.1.4. Anatomical structure

Anatomical structure includes number of vascular bundles and mechanical tissues. If the number of vascular bundles and amount of mechanical tissues are more, plants are more resistance to lodging.

3.1.5. Chemical composition

Cellulose and lignin contents in basal internode have been found to be associated with lodging. Plants which are rich in cellulose and lignin content are more resistance to lodging.

3.2. Root and crown characters

The anchorage of plants in soil depends on numerous plant morphological characteristics of roots such as number of roots per plant, root thickness, root width, and rooting depth. Sparsely populated plants have higher number of tillers with up to three crown roots, which helped to anchor in soil properly.

3.3. Mechanical properties

3.3.1. Straw stiffness – It refers to flexural rigidity of the culm.

3.3.2. Straw strength – The highest bending moment that the culm is capable of resisting.

3.3.3. Breaking strength – It refers to force required to break a section of certain length of basal culm internodes.

3.3.4. Root pulling resistance – This resistance is the vertical force required to pull out of soil a certain number of plants and is expressed as force per culm or per plant.

Traits	**Correlation with lodging resistance**	**Reference**
Plant height	–	Verma *et al*. (2005)
Stem/ internodal diameter	+	Kashiwagi *et al*. (2008)
Stem/ internodal wall thickness	+	Tripathi *et al*. (2003)
Panicle/ spike (weight)	–	Tripathi *et al*. (2003)
No. of vascular bundles	+	Ishimaru *et al*. (2008)
Mechanical tissues	+	Ishimaru *et al*. (2008)
Lignin/cellulose/hemicellulose content	+	Tanaka *et al*. (2003) Kong *et al*. (2013)
Si content in stem	+	Fallah (2008)

Table 1: Plant characters associated with lodging

4. Factors affecting lodging

4.1. Cultivar

Taller varieties tend to have weaker stems and will lodge easier than semi-dwarf varieties, which have stiffer straw. Plant height, stem thickness and straw density can affect the ability of the plant to resist a lateral force.

4.2. Light and temperature

Light intensity controls the balance between longitudinal and transverse development of vascular tissue. High intensity block the action of natural gibberellin which promotes both division and elongation of cells. Low light intensity promotes internode elongation and reduces culm wall thickness. Root growth may also be depressed by low light intensity. An indirect effect on the promotion of internode elongation through increased temperature may be due to its effect on release of soil nitrogen.

4.2.1. Effect of light intensity on maize lodging

The field experiment was conducted in China during 2012. Two maize cultivars Zhongdan 909, a lodging resistant cultivar and Xinyu 41, a commercial cultivar were used. Experiment consists of three shading treatments: unshaded, 30% shaded and 60% shaded. The shading treatments began 10 days before flowering, because 10 days before flowering is the most important time for the formation of maize stalk strength. The results found that lodging rate significantly increases as shading increases and is mainly due to the increase in lower intermodal length.

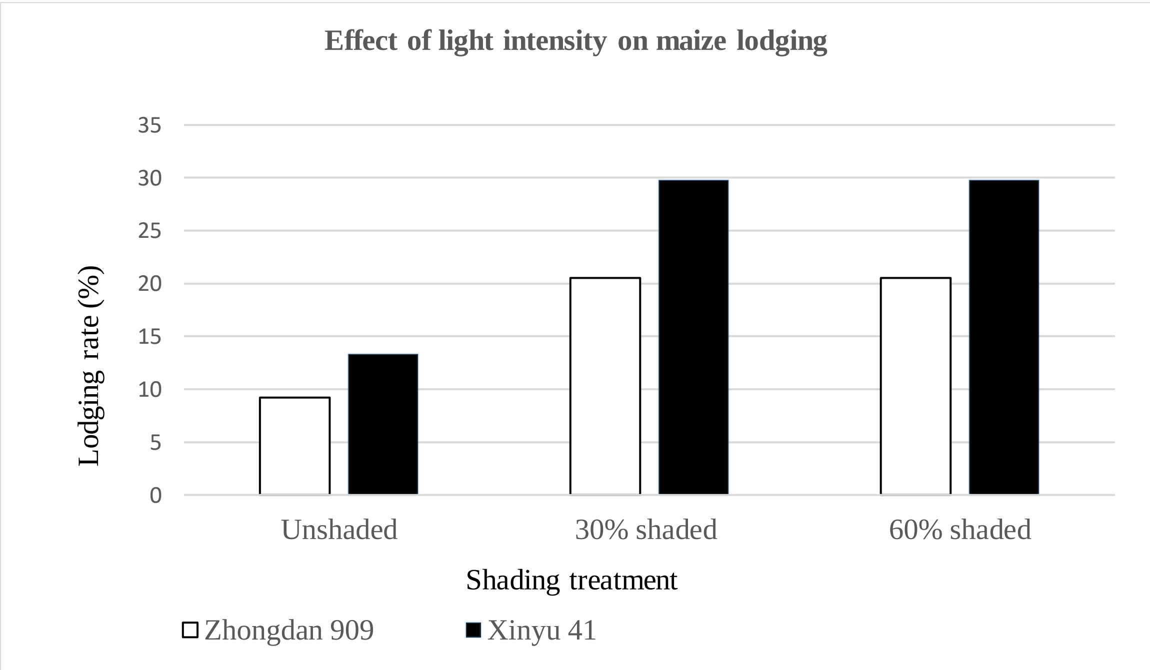

Figure 1: Effect of light intensity on maize lodging(Xue *et al*., 2016)

4.3. Soil type

Soil type can influence lodging. The black soil which have high percentage of organic matter, which gives a larger reservoir of N for plants, thereby increasing the risk of lodging.

4.4. Soil moisture and aeration

Excess soil moisture in the upper layer of soil weakens the anchorage of root system which promote lodging. Water stress results in weakened root systems as well as small stems and leaves. It sometimes weakens stem tissues, thereby increasing the possibility of lodging. Poor soil aeration may increase susceptibility to lodging due to effects of respiration inhibition and changes of metabolism which promotes cell elongation.

4.5. Fertilizer

Under excess nitrogen fertility, plants height tends to increase at the expanse of stem strength. Under extreme conditions lodging may occur very early in the life of plant. However, under high nitrogen fertility, tillering may be increased excessively and results in weak stem. When potassium is deficient in the soil, there is less sclerenchyma tissue produced in the stems and this condition causes the stem tissue to be weak. When plants are deficient in phosphorus, all parts of the plant grow at lower rates and both stems and roots tend to develop poorly. In this weakened condition, the stems and roots may be less able to resist the forces that cause lodging.

4.5.1. Lodging rate under different N levels

Field experiments were conducted at two eco-sites Taoyuan and Danyang in China during 2011. A super indica hybrid rice called Y Liangyou 2 was grown at each eco- sites under different N levels and results found that high N application decreases lodging resistance in rice by making plants taller and weakening the physical strength of the lower internodes.

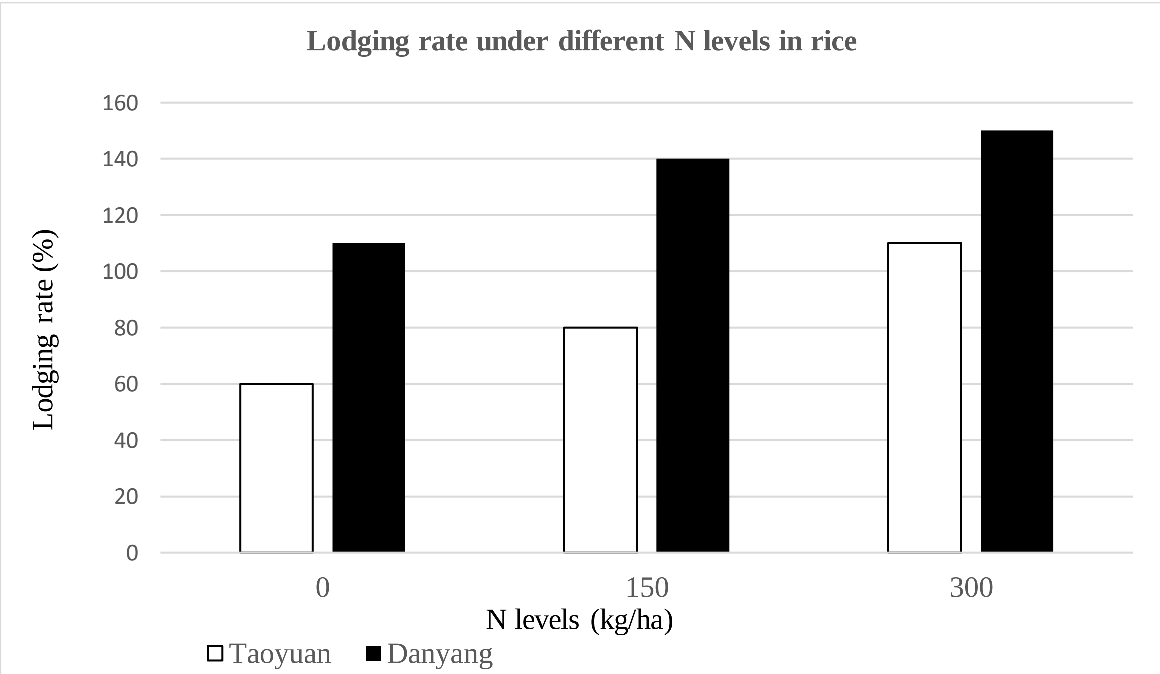

Figure 2: Lodging rate under different N levels in rice (Zhang *et al.*, 2016)

4.6. Plant density

When plants are planted too closely, they tend to elongate rapidly. As a result, stems become lighter and thinner, plants become susceptible to lodging. High plant populations modify the microclimate around plants, which affect lodging.

4.6.1. Effect of planting density on lodging rate

Field experiments were conducted in China during 2013. The experiment had a split-plot block design with four replications. The factors were variety (ChuanQiao-1 and XiQiao-1) as main plot, and plant density as sub plot. The study found that planting density significantly affected the agronomic traits, lodging resistance, and yield of tartary buckwheat. The plant height, internode number, first internode length, first internode diameter, number of first lateral root, and root volume are considered as the key characteristics affecting lodging incidence of tartary buckwheat. Growing tartary buckwheat at the density of 9×10^5 plant/ha was most beneficial to its growth. The yield of XiQiao-1 was higher than that of ChuanQiao-1. Therefore, XiQiao-1, planted at 9×10^5 plant/ha was recommended to produce the desired yield.

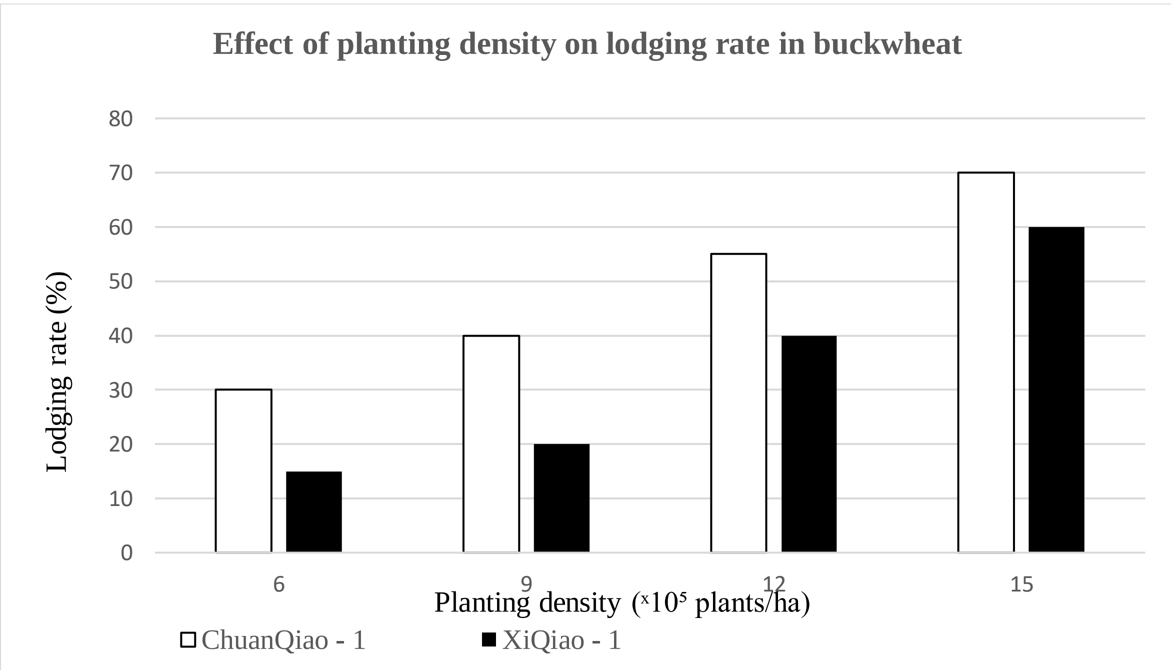

Figure 3: Effect of planting density on lodging rate in buckwheat (Xiang *et al.*, 2016)

4.7. Pests and diseases

Diseases, such as eyespot, foot rot, straw breaker foot rot *etc.* contribute to lodging. The wheat stem sawfly causes lodging in wheat and this reduces the lodging resistance.

4.7.1. Effect of sheath blight intensity on lodging

Field experiment was conducted in China during 2010. The experiment was conducted in the early season (April–July) and repeated in the late season (July–October) in the same field. Inoculation with *R.solani* and fungicide treatment provided convincing evidence that sheath blight decreased the breaking resistance of rice stem and increased the lodging rate.

	Inoculationwith *R. solani*	**Breaking resistance (g cm)**	**Lodging rate (%)**
Early season	-inoculation	249	319
	+inoculation	175	373
Late season	-inoculation	364	367
	+inoculation	316	388

Table 2: Effect of sheath blight intensity on lodging in rice(Wu *et al*., 2012)

5. Effects of lodging

5.1. Effects on crop growth

Plants that have lodged may shade other plants, thereby reducing the total amount of photosynthesis that can occur per unit area. When the stalks or stems of plants have broken, transfer of assimilates is restricted or stopped because of damage to vascular bundles. In plants, that have lodged, respiration continues in the upper parts of plants and depletes the stored carbohydrate reserve in other parts of plant. The weakest plant, following loss of stored carbohydrates become more susceptible to infection by diseases or damage by insects.

5.2. Effects on grain yield

The effect of lodging on grain yield is dependent on its severity and on the time of its occurrence. Lodging close to maturity cannot affect grain yield directly but may cause losses due to its interference with harvest. Lodging at heading effects both a number of kernels per head and individual kernel weight and lodging that occur later effects primarily kernel weight.

5.3. Effect on grain quality

Lodging may cause shrivelling of the grain and reduce its test weight. It may reduce milling quality of wheat. Sprouting in the heads has also been found to occur frequently in lodged than in standing crop.*In situ* seed germination may occur inlodged plants due to conducive environment especially forcultivars with weak seed dormancy. In addition, it also causes difficulties in harvest operations, increases demand for grain drying, and consequently results in increased production cost.

5.4. Physiological effects

The most obvious effect of lodging on the plant's physiological processes is its interference with carbohydrate assimilation. The protein in cereal grain originates primarily from nitrogen which has accumulated in the foliage prior to heading. Therefore, its absolute amount in the kernels is hardly affected by lodging, which occurs at heading or thereafter. Consequently the percentage of N or protein in the grain of lodged plants may rise due to decrease in carbohydrate accumulation. Lodging which involves culm breakage will also interfere with the translocation of carbohydrates and of minerals.

5.5. Effects on culm development and tillering

The elongation of the two upper culm internodes, which is not completed until 5-10 days after heading, can be affected by lodging which occurs up to this period. Since these internodes comprise about two thirds of the total culm length any interference with their development may affect straw yield considerably. Lodging may sometimes promote the development of late tillers, presumably because of the reduction in the competition for the minerals and carbohydrates by the lodging culms. However, these tillers rarely attain normal growth.

5.6. Effect on grain harvest

The moisture content of lodged grain will be higher than of un-lodged grain, which also interferes with the harvest and may increase the expenses for grain drying.

5.7. Incidence of disease in lodging crop

Some environmental factors and several plant characters which promote lodging also improve the growing conditions for root rots and leaf diseases. Moreover, these diseases are often favoured by the microclimate prevailing with in a lodged crop.

6. Management

Lodging can be controlled by adopting agronomic practices, use of plant growth regulators and also by crop improvement method.

6.1. Agronomic management

6.1.1. Cultivar selection

Cultivars with long plant height could be more susceptible to lodging, while those with shorter height plants sustained against lodging stress.Lodging can be prevented by selecting a variety that hasshort, strong straw. Heavier panicles may increase the bending moment of the basal internodes due to slender and longer top internodes. Plants with erect and semi erect panicles, as well as short panicles, resist lodging more efficiently than the cultivars with curved panicle types.

6.1.2. Method of planting and tillage

Lodging is more on ploughed land, because of reduction in soil physical strength due to intensive soil stirring and pulverising. Planting on raised beds is one of the better options to control lodging, it provide better drainage after excessive rainfall.Transplanting in rice favours the development of well established root system but in the case of direct seeded plants, they have tendency to develop shallower root system. Hence transplanted rice will have more resistance to lodging than direct seeded rice.

6.1.2.1. Effect of land preparation on lodging

The study was conducted to assess the impact of lodging on wheat yield in Pakistan. In this study, it was found that the incidence of lodging was less in raised bed planting than flat planting even under high dose of fertilizer. The lodged wheat in bed planting revived its stand after few days, which did not happen in flat planting. Similarly bed planting facilitated drainage of excessive rain water from the fields, which also helped avoiding lodging.

	Bed planting	**Flat planting**
Total area sown(ha)	31.60	31.60
Lodged (ha)	6.50	10.90
Non lodged (ha)	25.10	20.70
Lodging (%)	20.50	34.60

Table 3: Effect of land preparation on lodging in wheat (Ahmadand Mahmood, 2005)

6.1.3. Date of Sowing

For each crop and cultivar there are optimum dates of planting with lodging usually being less when crop is planted at optimum time. When winter cereals are planted too early, the vegetative growth may be excessive, thereby increasing susceptibility of plants to lodging.

Excessively late planting of spring grain may increase lodging because rapid growth associated with high temperatures may produce weak stems.

6.1.3.1. Effect of sowing date on culm lodging resistance

Field experiment was performed in 2013 at the experimental station of Dongwu village, in China. Two widely planted cultivars, Tainong 18 and Shannong 15 were selected as the experimental plants. Early, normal, and late sowing were performed on October 1, 8, and 15 respectively. The result showed that late sowing significantly reduced the risk of lodging by reducing the length of lower internode, plant height and increasing the diameter and cell wall thickness of internodes.

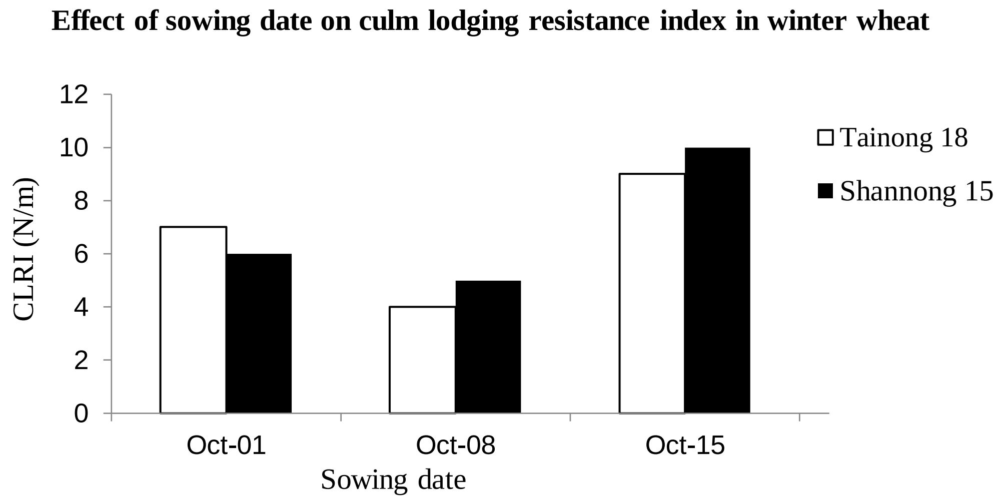

Figure 4: Effect of sowing date on culm lodging resistance index (Dai *et al.*, 2017)

6.1.4. Method and depth of sowing and row orientation

Deep sowing increases the depth at which the root crown is located and also its length. This may strengthen the anchorage of plants in the soil and thus increases their lodging resistance. Sowing in drill rows in a direction parallel to that of prevailing strong wind may reduce the incidence of stem lodging.

6.1.5. Plant spacing

The establishment of proper and uniform spacing between plants encourages healthy plant growth and permit plants to resist the attack of unpredictable hazards such as storms, heavy rains and diseases. Crowded or sparsely spaced plants tend to lodge.

6.1.6. Fertilizer

Careful monitoring of fertilizer application, especially nitrogen is effective in preventing the lodging. Timing of nitrogen application is particularly important in this context. Dividing the nitrogen into two or three splits and applying as needed by crop plant helps to reduce lodging. The balance of N, P and K in the soil must also be given proper attention.Potassium helps to build cellulose needed for stalk and stem strength, increases root growth and retard crop diseases.Silicon application increases the stiffening of the culm and leaves, rigidity of stalk**,** lignin content and also improves the leaf angle to harvest more light and reduces the shading effect.

6.1.6.1. Effect of K application on root dry weight

An experiment was under taken in a glass house at the university of New England to investigate the effect of K fertilizer on rice growth using a standard rice variety similar to that grown in Amber 13, two semi dwarf variety known to have different susceptibility to lodging were used for comparison and results found that application of K significantly increases the tiller number, root dry matter production and stem diameter. Lodging occurred primarily from the base, due to poor root growth in the absence of K.

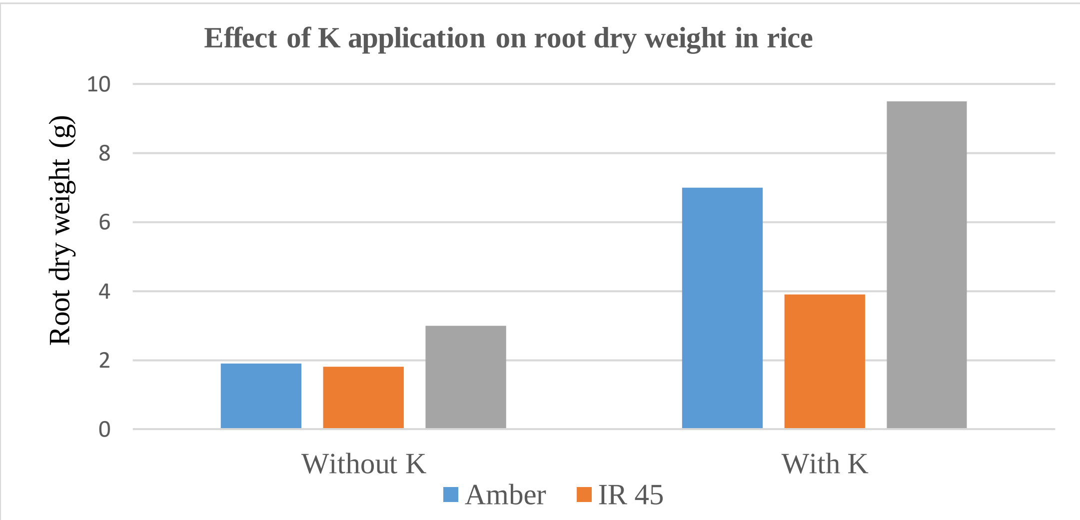

Figure 5: Effect of K application on root dry weight in rice(Bhiah *et al.*, 2010)

6.1.6.2. Effect of silicon on lodging of rice

Hydroponic culture experiments were conducted in 2006 at the green house of Rice Research Institute in Iran. A high yielding Iranian rice variety Nemat was used for this experiment. The experiment showed that lodging index decreased with increase in silicon concentration.

Silicon (ppm)	Plant height (cm)	Culm thickness (mm)	Lodging index (%)
0	70.85	24.80	215.10
50	74.13	26.56	178.50
100	74.73	29.18	168.30

Table 4: Effect of silicon on lodging of rice under hydroponic culture (Fallah, 2012)

6.1.7. Irrigation practices

Appropriate irrigation and drainage promote root and above ground plant growth, thus reducing the incidence of lodging. Reduction in early vegetative growth and plant height greatly reduce susceptibility to lodging during and following later irrigation. Restriction of excessive vegetative growth by delaying or with holding first irrigation reduces the lodging.Applying water by sprinklerirrigation promoted lodging when applied at early vegetativegrowth stage with higher plants, so the irrigation by sprinkler irrigation should be withhold until plantreached the booting stage. As at this stage, roots can be fullygrown and can provide better anchorage. Further, flood irrigationcan make the soil soft enough that roots reduce theiranchorage in soil and promote lodging.

6.1.8. Mixed cultivation and crop rotation

Mixed cultivation of cereals with other crops can be a useful approach to reduce lodging potential. The blending of different crops results in reducing the effect of wind to avoid lodging.Crop rotation reduces disease incidence; e.g., a close sequence of wheat and other cereals on which the disease can survive will promote its incidence.

6.2. Use of plant growth regulators

Plant growth regulators are chemically synthetic compounds that are used to reduce plant height and other lodging associated plant traits. These regulators reduces cell division and elongation particularly in culms of cereals. These are classified on the basis of their specific function. Some are employed to inhibit gibberellic acid biosynthesis pathway, while some are applied to produce more ethylene. Ethephon is the most commonly used ethylene-releasing compound used on cereals. Chlormequat chloride, mepiquat chloride, and trinexapac-ethyl block gibberellic acid biosynthesis and thus helps in controlling lodging in cereals (Shah *et al*., 2017).

6.2.1. Effect of mepiquat chloride on lodging rate

Kamran and co-workers conducted an experiment in China during 2015–2016. The maize hybrid, Zhongdan (ZD 958), a popular hybrid was used in this experiment. Maize seeds were surface dressed with mepiquat chloride at the rate of 0, 2.0, 2.5, and 3.0 g/kg before sowing. Application of mepiquat chloride significantly decreased the lodging rate and minimum lodging rate was observed when it applied at the rate of 2.5 g/kg. This decreased lodging percentage is associated with a reduction of plant height, enhanced culm mechanical strength, stem diameter and accumulation of more lignin content in the maize basal internodes, which strengthened the lodging resistance of maize.

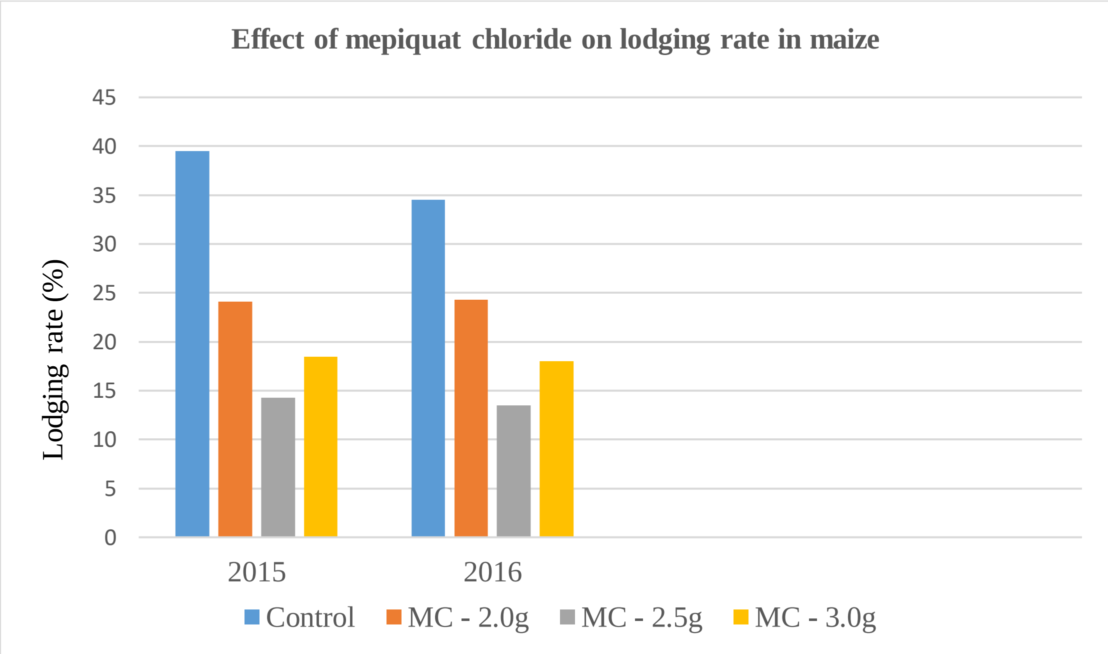

Figure 6: Effect of mepiquat chloride on lodging rate in maize (Kamran *et al.*, 2018)

6.2.2. Effect of ethephone on plant height

Tripathi and co-workers conducted a field experiment at CIMMYT in Mexico during 1997–1998 and 1998–1999. The experiment was conducted as a randomized complete block with a split plot treatment design. Main plots were 180, 240 and 300 kg N/ha and 300 kg N/ha + ethephon (480 g /ha) and subplots were 12 genotypes, 8 from Mexico and 4 from India. The result showed that ethephon application increased stem wall thickness and tillers and decreased the plant height.

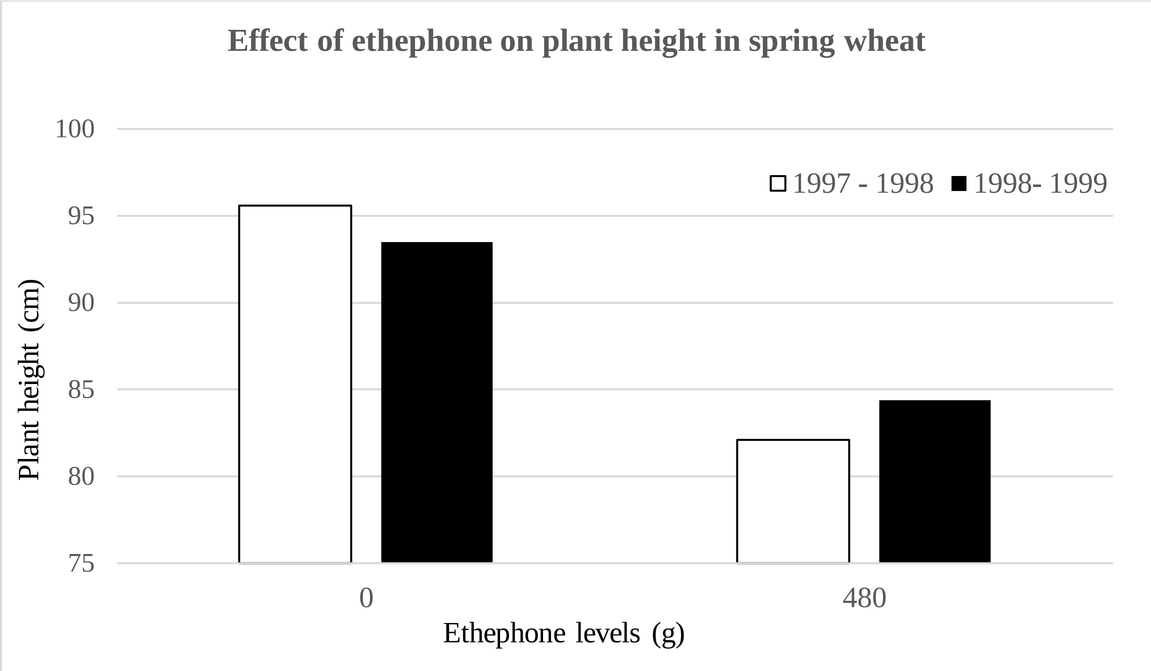

Figure 7: Effect of ethephone on plant height in spring wheat (Tripathi *et al*., 2003)

6.3. Crop improvement

Crop lodging can be improved by the introduction and identification of genes associated with lodging resistance. Genes and QTLs associated with lodging resistance in wheat and rice are given below.

6.3.1. Lodging resistant genes

Genes	Impact on plant traits	Reference
Wheat		
Rht1 and *Rht2*	Reduce internode length and plant height	Pearce *et al*., 2011
Rht3	Reduce plant height	Shearman *et al*., 2001
Rht5 and *Ppd-D1*	Reduce plant height	Rebetzke *et al*., 2012
Rht24	Dwarfing genes	Tian *et al*., 2017
Rice		
sd1	Reduce plant height	Liu *et al*., 2018
OsCesA1,*OsCesA3* and *OsCesA8*	Cellulose synthases	Wang *et al*., 2010

Table 5: Genes associated with lodging resistance in wheat and rice

6.3.2. QTLs in lodging breeding

Chromosomes/(QTLs)	Impact on plant traits	Reference
Wheat		
1BS, 4AS, 7BL	Shorter plant height	Keller *et al*., 1999
2AS, 3AS, 5AL	Culm wall thickness	Keller *et al*., 1999
QSd-3B	Culm diameter	Hai *et al*., 2005
Rice		
Chr. 1 (SCM1)	Culm strength	Ookawa *et al.*, 2010
Chr. 6 (SCM2)	Culm strength, increased spikelet number and grain yield	Ookawa *et al.*, 2010
Chr.1, 3, 6, 7, 8, 12	Culm diameter	Kashiwagi *et al*., 2004
Chr. 2 (SCM4)	Culm lodging resistance	Ookawa *et al.*, 2010

Table 6: QTLs identified for lodging resistance in wheat and rice

7. Conclusion

As lodging causes considerable yield reduction in crop plants, managing lodging induced adversities or enhancing lodging resistance in cereals is important in enhancing food grain production.

8. Discussion

1. How raised bed planting system reduces the lodging rate?

Bed planting ensures drainage of excessive rain water from the fields, which helps to avoid lodging.

2. Whether mechanical harvesting is possible for harvesting lodged crop?

No. Mechanical harvesting is not possible for lodged crops.

3. How temperature affect lodging?

An indirect effect on the promotion of internode elongation through increased temperature may be due to its effect on release of soil nitrogen. At high temperature availability of N will be more, high N increases the lodging rate by making plant taller.

4. How crop lodging effect straw yield?

The elongation of the two upper culm internodes, which is not completed until 5-10 days after heading, can be affected by lodging which occurs up to this period. Since these internodes comprise about two thirds of the total culm length any interference with their development may affect straw yield considerably.

5. Role of root characters in lodging resistance?

If the number of roots, thickness and root volume is high, plants will have more anchorageand reduces the root lodging.

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Department of Agronomy

Agron. 591: Masters Seminar

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Major Advisor : Dr. Anitha S.

Venue : Seminar Hall
Date : 10 - 01 - 2020
Time : 10.00 am

Crop lodging and management

Abstract

Lodging is one of the most important constraints limiting the quality and yield in crop production. It is the state of permanent displacement of the stem from its upright position. It is common in all cereals and other crops like rapeseed and sunflower. Cereals generally exhibit two types of lodging, stem lodging and root lodging. Both stem lodging and root lodging can occur, singly or together, and can reduce growth and yield. It is often not distributed uniformly throughout an affected field but may be scattered over certain sections or spots.

Climate, soil, as well as plant factors affect lodging. Xiang *et al*. (2016) reported that high plant density in buckwheat, decreased theamount of light available to plants, leading to lodging due to taller plants, smaller stem diameters and elongatedlower internodes. High N application decreases lodging resistance in rice by making plants taller and weakening the physical strength of the lower internodes (Zhang *et al*., 2016).

Lodging alters plant growth and development, affects flowering, and reduces photosynthetic capabilities of the plant, hence affecting carbohydrate assimilation. Severe lodging interferes with the transport of nutrients and water from the soil. Lodging often contributes to uneven maturity, high moisture content and loss of grain quality due to sprouting and fungal infection. Lodging of cereals results in increased cost for harvest and grain drying.

Lodging can be controlled by adopting agronomic practices, use of plant growth regulators (PGRs) and crop improvement. Agronomic practices include cultivar selection, method of planting and tillage, date of sowing, depth of sowing, row orientation, plant

population, fertilizer application, irrigation practices and crop rotation.Ahmadand Mahmood (2005) reported that lodging incidence was lesser in raised bed planting than flat planting system even under high dose of fertilizer. In wheat, delay in sowing by two weeks could reduce the lodging rate (Dai *et al*., 2017).

Use of growth regulators can reduce plant height and other lodging associated plant traits. Most growth regulators act by reducing cell division and elongation in cereals as well as by inhibiting gibberellin biosynthesis. Tripathi *et al*. (2003) reported that application of ethephon prevented lodging, mainly due to decrease in height, reduction in panicle length and internode length, and increased stem wall thickness. Crop improvement includes identification and introduction of genes associated with lodging to sustain cereal productivity in lodging prone areas.

As lodging causes considerable yield reduction in crop plants, managing lodging induced adversities or enhancing lodging resistance in cereals is important in enhancing food grain production.

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