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Assessment of Performance in Cereal Fodder Crops with Relation to Seeding Rates and Cutting Stages

ABSTRACT

Cereal fodder crops serve as indispensable sources of nutrition for livestock, contributing significantly to the efficiency and sustainability of animal production systems worldwide. Maximizing the productivity and quality of these crops requires careful management, with seed rates and cutting stages playing pivotal roles in determining crop performance. Seeding rates play a critical role in crop establishment and growth, with both low and high rates affecting plant competition and ultimately yield. Cutting stages, on the other hand, are pivotal in determining the quality and nutrient composition of the forage. Optimal cutting stages vary depending on the intended use, such as hay, silage, or grazing and can significantly influence digestibility and overall nutritional value. The assessment of cereal fodder crops is therefore pivotal for optimizing agricultural productivity and ensuring sustainable livestock feed production. Understanding the intricate relationship between seeding rates, cutting stages and crop performance is essential for sustainable agriculture and livestock production systems, contributing to improved resource efficiency and economic viability.

Keywords: Cereal fodder crops, Cutting stages, Livestock feed, Productivity, Quality, Seed rates

1. INTRODUCTION

Cereal fodder crops play a tremendous role in global agricultural sector, serving as essential components of livestock feed, thus contributing significantly to agricultural prosperity, productivity and sustainability. From 1993 to 2020, there is expected to be a twofold increase in the demand for livestock products, while meat and milk production in developing countries will see annual growth rates of 2.7% and 3.2%, respectively. [1]. The performance of cereal fodder crops, however, is intricately linked to various agronomic factors. Among the various factors influencing the performance of cereal fodder crops, seed rates and cutting stages have been identified as critical determinants of forage yield and quality. Initially, the focus of cereal crop improvement was primarily on enhancing grain yield, leading to the release of numerous dwarf, high-yielding varieties. However, in more recent times, there has been a growing acknowledgment of the importance of crop residues for livestock feed.

31 Consequently, there has been a shift in emphasis towards developing dual-purpose cultivars
32 [2].

33 Among the diverse array of fodder crops, cereals such as barley, fodder maize, oats and
34 wheat hold particular importance due to their adaptability, nutritional value and yield
35 potential. These crops are widely used as feed for livestock, particularly for large ruminants
36 such as cattle, sheep, and goats. The straw and stover of these crops are also important
37 sources of livestock feed.

38 Wheat (*Triticum aestivum*) is the most important cereal crop in the world and it is widely
39 used as a fodder crop. Wheat straw is an important fodder throughout the temperate and
40 subtropical areas, and it is often grazed in winter in areas where this is possible. In parts of
41 the Himalayan region, wheat is cut as fodder in times of scarcity, but it is less productive
42 than oats. Wheat is also used as a silage crop, particularly in small-scale farming. Barley
43 (*Hordeum vulgare*) is the second most important widely used fodder crop. Barley is
44 important for malting as well as for human and livestock food. It is often used as a feed for
45 pigs, poultry, and ruminants. Barley straw is also used as a fodder, particularly in small-scale
46 farming. Oats (*Avena sativa*, *A. byzantina*, and *A. strigosa*) are a tall, annual cereal that is
47 widely grown as a fodder in temperate and subtropical countries. Oats are often used as a
48 feed for horses, cattle, and sheep. Oat straw is also used as a fodder, particularly in small-
49 scale farming. Rye (*Secale cereale*) is an annual cereal that is widely used for winter pasture
50 in North America and as a minor cereal in parts of Europe. It is adapted to poor soils and
51 severe winters. It is often used as a feed for cattle, sheep and pigs. Rye straw is also used
52 as a fodder, particularly in small-scale farming. Maize (*Zea mays*), also known as corn in
53 North America, is a warm-season crop that is grown wherever summers are warm enough
54 and rainfall or water supply is adequate. It is important as fodder, with the grain widely used
55 in livestock feed, the stover fed to livestock, especially in the developing world, and the crop
56 grown specifically as fodder on a large scale. Tropical maizes may reach 4 meters in height,
57 while those in temperate and subtropical areas are mostly under 2 meters. Maize is the
58 supreme silage crop, and it is often used as a feed for pigs, poultry, and ruminants. In
59 addition to these common cereal fodder crops, there are also other plants that are
60 specifically grown for fodder, such as alfalfa (*Lucerne*), clover, grass and millet. They are
61 often used as a source of protein and energy, and they are often used in combination with
62 cereal crops to provide a balanced diet for livestock.

63 In recent years, the optimization of seed rates as well as cutting stages has garnered
64 increasing attention from agronomists, researchers and farmers alike, driven by the
65 imperative to enhance fodder crop yields while maintaining nutritional integrity. These
66 interplay between seed rates and cutting stages represents a complex dynamic, influenced
67 by factors such as climate conditions, crop genetics, soil fertility and management practices.

68

69 **2. IMPACT OF SEED RATES ON CROP PERFORMANCE**

70

71 Research has demonstrated that seed rates significantly affect the productivity and quality of
72 cereal fodder crops. The significance of seeding rates in cereal fodder crop production lies in
73 their direct impact on stand establishment, plant density and subsequent biomass
74 accumulation. The productivity and quality of cereal fodder crops are influenced by a range
75 of physiological processes, including tillering, biomass allocation and nutrient assimilation
76 [3]. Seed rates directly affect plant population density with higher rates typically resulting in
77 greater competition for resources and increased tillering capacity. Higher seed rates can
78 result in increased biomass accumulation and fodder yield, particularly in the early stages of
79 crop growth [4]. However, the relationship between seed rate and yield is not linear and
80 there exists an optimal seeding density that maximizes yield without compromising quality
81 [5]. Excessive seed rates may lead to overcrowding, reduced individual plant size and
82 increased susceptibility to lodging. A study found that fodder-based intercropping systems
83 significantly affected the quality of fodder [6]. It revealed that intercropping cereals with

84 legumes improved the protein concentration of the fodder, making it more nutritious for
85 livestock. Similarly, maturity of the crops also affected the production efficiency, nutritive
86 value and in-situ nutrients digestibility of three cereal fodders [7]. The study revealed that
87 cereal fodders harvested at maturity had a higher crude protein (CP) level than those
88 harvested at earlier stages. Excessive seeding rates may lead to intra-specific competition
89 for resources, reducing individual plant size, tiller number and decrease yield by increasing
90 disease pressure, insects, and lodging [8]. Conversely, low seed rates may result in sparse
91 stands, inefficient resource utilization and ultimately yield [9]. Therefore, optimal seeding
92 rates must strike a balance between achieving an adequate plant population to maximize
93 light interception and resource utilization while avoiding excessive competition among plants,
94 which can lead to lodging, disease susceptibility, and reduced overall productivity. Moreover,
95 seeding rates exert profound effects on crop architecture, influencing factors such as tillering
96 capacity, stem diameter, and biomass allocation, all of which have implications for fodder
97 quality and digestibility.

99 **3. INFLUENCE OF CUTTING STAGES ON CROP YIELD AND QUALITY**

100 Cutting stage is an important factor in determining the quality and yield of cereal crops used
101 for hay, silage, or grazing. It represent a critical management decision point in cereal fodder
102 crop production, determining the timing of harvest relative to crop development and
103 physiological maturity. The choice of cutting stage profoundly influences not only biomass
104 yield but also nutritional composition, digestibility and regrowth potential. It influences the
105 balance between vegetative growth and reproductive development, with early cutting
106 promoting leafy biomass accumulation and late cutting favoring seed or grain production
107 [10]. The timing and frequency of cutting events profoundly impact the yield and quality of
108 cereal fodder crops. For hay, the crop should be cut at the milky stage, before the stems
109 become woody, and then tied into sheaves and dried in the field. This stage is typically
110 reached when the kernels on the seed head begin to thicken and if squeezed, a white, milky
111 substance is visible. For silage, the crop should be cut at the boot to early head stage, when
112 the seed head swells in the flag leaf sheath but has not yet emerged. This stage allows for
113 optimal fermentation and preservation of nutrients. For grazing, plants can be grazed when
114 8-10 inches tall during rapid spring growth. Encouraging spring tillering with nitrogen
115 applications at dormancy break/spring green-up can enhance forage quality and yield. Early
116 cutting stages promote the accumulation of leafy biomass, which is often higher in protein
117 content and digestibility compared to mature stems. It may prioritize forage quality, capturing
118 peak levels of protein, digestible fiber and energy at the expense of total biomass yield.
119 However, frequent cutting at early stages may impede plant regrowth and reduce overall
120 biomass production over time [11]. On the contrary, late cutting stages, while maximizing
121 total biomass yield, may result in lower forage quality due to increased lignification and
122 reduced nutrient content [12]. Balancing the trade-offs between yield and quality requires
123 careful consideration of factors such as crop growth stage, weather conditions and livestock
124 nutritional requirements [13]. Hay quality evaluation of summer grass and legume forage
125 monocultures and mixtures grown under irrigated conditions significantly affected the
126 nutritive value of the fodder [14]. The study found that cereal fodders harvested at the
127 vegetative stage had a higher CP level than those harvested at the reproductive stage.
128 Similarly, researchers found that the feed value of alfalfa (*Medicago sativa* L.) harvested at
129 different maturity stages significantly affected the nutritive value of the fodder. The study
130 found that alfalfa harvested at the early flowering stage had a higher CP level than those
131 harvested at the late flowering stage [15]. Integrated management approaches that
132 incorporate both seed rates and cutting stages can help optimize forage production while
133 maintaining nutritional value and feed efficiency. A study revealed that cutting stage
134 significantly affected the yield of cereal fodder crops. The study revealed that cutting at the
135 early vegetative stage resulted in higher forage yield and CP level [16]. However, the study
136

137 also found that cutting at the early vegetative stage decreased the NDF level, making the
138 fodder less fibrous. Another study reported that cutting stage significantly affected the
139 nutritive value of cereal fodder crops. Cutting at the early vegetative stage resulted in higher
140 CP and IVDDM levels [17]. However, the study also found that cutting at the early vegetative
141 stage decreased the NDF level, making the fodder less fibrous.

142 The cutting stage therefore significantly impacts the nutritional value of cereal fodder crops.
143 The nutritional quality of fodder primarily depends on the species composition and its
144 developmental stage, both of which are influenced by climatic conditions impacting mineral
145 content, regrowth capacity, sward structure and botanical makeup [18]. Harvesting at the
146 correct stage is thus crucial to ensure optimal nutrient content and digestibility. For instance,
147 cutting cereal crops at the boot to early head stage for silage or at the milky stage for hay
148 can help preserve essential nutrients and maintain high-quality forage. Therefore, proper
149 timing of the cutting stage is essential to maximize the nutritional quality of cereal fodder
150 crops for livestock feed.

151 Despite the recognized importance of seeding rates and cutting stages in cereal fodder crop
152 production, a comprehensive understanding of their interactive effects and optimal
153 management strategies remains elusive. Existing literature offers valuable insights into the
154 individual impacts of seeding rates and cutting stages on fodder crop performance, yet a
155 synthesis of this knowledge is warranted to inform evidence-based management decisions
156 and drive innovation in fodder crop production systems. By understanding the physiological
157 basis of seed rates and cutting stages, growers can make informed decisions to optimize
158 crop growth and development while maximizing forage yield and quality.

159

160 **4. INTERACTION EFFECTS AND MANAGEMENT STRATEGIES**

161

162 The interactions between seed rates and cutting stages complicate crop management
163 decisions, requiring growers to adopt integrated approaches that consider both practices
164 simultaneously. Research has shown that the combined effects of seed rates and cutting
165 stages on crop performance are often non-linear and context-dependent. For example,
166 higher seed rates may mitigate the negative effects of early cutting by increasing tiller
167 density and compensatory growth potential [19]. Conversely, late cutting stages may offset
168 the yield benefits of high seed rates by limiting regrowth capacity and reducing forage quality
169 [20]. Therefore, growers must tailor their management strategies to specific cropping
170 conditions, taking into account factors such as soil type, climate variability and livestock
171 feeding requirements [21]. Integrated crop management practices that optimize seeding
172 density, cutting timing, and nutrient management can help maximize forage production and
173 quality while minimizing environmental impacts and resource inputs.

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175 **5. INTERCROPPING AND CEREAL FODDER CROP PERFORMANCE**

176

177 Intercropping that involves growing two or more crops simultaneously on the same piece of
178 land has been found to improve the yield and nutritional quality of forage crops. A study
179 registered that legume-cereal intercropping significantly improved forage yield, quality and
180 degradability [22]. Intercropping improved the CP level of the fodder, making it more
181 nutritious for livestock. Similarly, cereal-legume forages had higher productivity and
182 profitability than monoculture cropping systems [23]. The study reveals that intercropping
183 improved the soil nutrient status, leading to higher yields and better quality fodder.
184 Intercropping fodder maize crops with legumes also significantly improved the yield, CP
185 level, soil nutrient status and quality of the fodder [24].

186

187 **6. EFFECT OF HARVEST TIMING ON THE NUTRITIONAL QUALITY OF** 188 **CEREAL FODDER CROPS**

189

190 The timing of cutting cereal fodder crops significantly affects their nutritional value. Research
191 indicates that later cutting stages can improve digestibility and digestible energy intake,
192 resulting in a higher yield of forage per acre. This is because the plant has more time to
193 accumulate nutrients, particularly starch, which can offset the contribution of neutral
194 detergent fibre (NDF) towards energy supply. Harvesting at the late milk to early dough
195 stage for barley and the late milk stage for oats can improve digestible nutrient yield without
196 sorting, ruminal fermentation, ruminal digestibility, or total-tract digestibility. Total-tract starch
197 digestibility tends to increase with advancing maturity, from 60% digestible at the late-milk
198 stage up to 80% at the mature stage for oats. However, the increase in forage yield is likely
199 to vary from year to year depending on growing conditions. The chemical analysis of whole-
200 crop forage samples revealed more feed-quality advantages than drawbacks as the crops
201 advanced. There were significant differences in nutrient composition from the late-milk stage
202 to the hard-dough stage, but very little change from then to maturity. Overall, organic matter
203 and non-fibre carbohydrates (total starch and sugar except those tied up in cell walls)
204 increased as the crops advanced. However, there were some disadvantages to later cutting
205 stages, such as decreased calcium and crude protein (CP) content. Although phosphorus
206 decreased, this is not viewed as a disadvantage because phosphorus content in cereals is
207 on the high side relative to calcium. The forages were put to the true test for feed quality in a
208 feeding trial coupled with a metabolism study involving ruminally cannulated animals. The
209 results showed that animals fed rations containing cereal forages cut at the hard-dough and
210 mature stages had lower rumen pH levels than those fed rations containing cereal forages
211 cut at earlier stages. This indicates that the additional starch in the later-cut forages is
212 digestible. Harvesting cereal fodder crops at the hard-dough stage has the potential to
213 improve digestible nutrient yield without sorting, ruminal fermentation, ruminal digestibility or
214 total-tract digestibility. However, there are some cautions to consider, such as a potential for
215 grain loss due to shelling in the field, the need to provide calcium and protein to balance the
216 diet, and the chance that feeding cereal forages cut at later stages of maturity could cause
217 acidosis. Susceptibility to acidosis varies among animals, and producers should consult with
218 their nutritionist to make appropriate ration adjustments.

219

220 **7. RECOMMENDED CUTTING STAGES OF VARIOUS CEREALS**

221

222 The recommended cutting stages for cereal fodder crops vary depending on the crop type
223 and the desired outcome. For barley, it is recommended to harvest at the whole crop stage
224 for silage, while oats or triticale provide better leaf yield if crops are cut at the green chop
225 stage. *Triticale* can be harvested at either the green chop or whole crop stage, with the
226 whole crop stage maximizing yield and carbohydrate content and the green chop stage
227 maximizing protein content at the expense of yield and carbohydrate. Harvesting between
228 these stages is not advised as it fails to produce optimum yield or quality. For oat crops,
229 harvesting for silage (GCCS) should only be done at the booting stage, as this species is not
230 ideal for whole crop cereal silage. Barley is recommended to be harvested at the whole crop
231 stage, with either oats or triticale providing better leaf yield if crops are cut at the green chop
232 stage. Harvesting at the flag leaf or boot to early ear emergence stage for cereal crops
233 requires the crop to be wilted to reach the desired DM content before harvesting, particularly
234 for cereal and legume mixtures. Mowing with a roller type mower conditioner is
235 recommended to crimp or crack the stems, which will encourage wilting and increase the
236 rate of wilting by 20 to 40% compared to mowing only. Tyned type mower conditioners will
237 also increase the rate of wilting through mainly an abrading (bruising) action on the stems.

238

239 **8. FACTORS TO CONSIDER WHEN DETERMINING SEEDING RATE FOR**
240 **CEREAL FODDER CROPS**

241

242 When determining the seeding rate for cereal fodder crops, several factors need to be
243 considered to optimize forage production and quality. These factors include:

244

245 **8.1. Planting Date:** Following recommended planting dates is crucial for maximizing forage
246 potential. Early planting enhances total forage production, while late planting can limit
247 hay or silage production potential.

248 **8.2. Seeding Rates:** Seeding rates for small grain cereals should be adjusted based on the
249 intended use. For fall grazing, seeding rates should be 25 to 50% higher than normal to
250 provide forage earlier in the fall. Thicker plantings can reduce stem size and make
251 curing or ensiling easier.

252 **8.3. Fertilization:** Adequate fertilizer amounts, particularly nitrogen, are essential for
253 maximizing forage production. Small grain cereals respond well to nitrogen, and
254 increased rates are recommended when grown for pasture. Soil testing and following
255 fertilizer recommendations are crucial for optimal growth.

256 **8.4. Species Composition:** The choice of cereal species and potential mixtures, such as
257 cereal-pea mixtures, can impact forage quality and yield. Adding peas to cereals can
258 improve forage quality, but it may not necessarily increase yields.

259 **8.5. Plant Health Concerns:** Consideration should be given to potential plant health
260 concerns, such as nitrate poisoning, especially when selecting species for hay or silage
261 production. Cereal fodder crops play a crucial role in providing essential nutrients for
262 livestock feed, but their production faces numerous challenges, including climate
263 change, water scarcity, soil quality issues, pests, diseases, and weeds

264

265 **9. CHALLENGES OF GROWING FODDER CROPS**

266

267 Cereal fodder crops play a crucial role in providing essential nutrients for livestock feed, but
268 their production faces numerous challenges, including climate change, water scarcity, soil
269 quality issues, pests, diseases, and weeds

270

271 **9.1. Climate Change:** Changing climatic conditions, like droughts and heatwaves, pose a
272 significant threat to cereal fodder crop yields and quality. Collaborative research and
273 engagement with producers are essential to develop resilient crop varieties and
274 agronomic practices.

275 **9.2. Water Scarcity:** In semi-arid regions, water scarcity limits cereal fodder crop
276 production. Traditional methods like fallow years help, but innovative solutions such as
277 drought-tolerant varieties and efficient irrigation systems are needed.

278 **9.3. Soil Quality:** Poor soil quality, characterized by low fertility and structure, affects crop
279 productivity. Implementing soil management practices like organic fertilization and crop
280 rotation is crucial for improving soil quality.

281 **9.4. Pests and Diseases:** Pests and diseases can devastate cereal fodder crops, leading
282 to yield losses. Integrated pest management strategies, including resistant varieties
283 and biological control methods, are necessary to minimize their impact.

284 **9.5. Weeds:** Weeds compete with crops for resources and reduce yields. Effective weed
285 management practices like herbicide use and crop rotation are essential for
286 maintaining crop productivity.

287

288 **10. FUTURE PROSPECTS**

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290 . The assessment of cereal fodder crop performance concerning seeding rates and cutting
291 stages presents promising avenues for future research and practical application. Further
292 exploration could focus on:

293

294 **10.1. Optimization of Seeding Rates:** Investigating the optimal seeding rates tailored to
295 specific cereal fodder crops and environmental conditions could enhance yield and
296 quality. Employing advanced techniques such as precision agriculture and remote
297 sensing may provide insights into achieving maximum productivity while conserving
298 resources.

299 **10.2. Fine-Tuning Cutting Stages:** Delving deeper into the effects of different cutting
300 stages on crop yield, nutrient content, and regrowth potential can refine management
301 practices. Long-term studies assessing the sustainability of various cutting regimes on
302 soil health and biodiversity are imperative for informed decision-making.

303 **10.3. Climate Resilience:** With changing climatic patterns, there's a need to evaluate how
304 cereal fodder crops respond to varying temperature and precipitation regimes.
305 Research into cultivar selection, agronomic practices, and alternative cropping systems
306 can aid in mitigating climate-induced challenges and ensuring stable fodder production.

307 **10.4. Integrated Management Approaches:** Exploring integrated crop management
308 strategies incorporating seeding rates, cutting stages, irrigation, fertilization, and pest
309 control can optimize productivity while minimizing environmental impact.
310 Interdisciplinary collaborations between agronomists, ecologists, geneticists, and
311 economists can foster holistic solutions for sustainable fodder production.

312 **10.5. Technology Adoption:** Embracing innovative technologies such as precision
313 agriculture, drone-based monitoring, and data analytics can revolutionize cereal fodder
314 crop management. Integrating digital tools for real-time decision support systems and
315 farm-level automation holds immense potential for enhancing efficiency and
316 profitability.

317 **10.6. Economic Viability and Market Demand:** Assessing the economic feasibility of
318 different seeding rates and cutting regimes in relation to market demand for fodder
319 products is crucial for farmer adoption. Conducting market surveys and value chain
320 analyses can identify opportunities for niche markets and value-added products.

321 **10.7. Extension and Outreach:** Facilitating knowledge dissemination and capacity
322 building among farmers through extension services, training programs, and
323 demonstration plots can promote the adoption of best management practices.
324 Engaging stakeholders including farmers, policymakers, and industry representatives
325 in participatory research initiatives can ensure relevance and uptake of research
326 findings.

327

328 **11. CONCLUSION**

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330 Optimizing cereal fodder crop management requires a holistic approach that integrates
331 seed rates and cutting stages to maximize productivity and quality. By understanding the
332 physiological basis of these management practices and their interactions, growers can
333 make informed decisions to enhance forage production efficiency and sustainability.
334 Future research should focus on developing innovative management strategies that
335 address the complexities of modern livestock production systems while promoting
336 environmental stewardship and resilience to climate change. Through collaborative
337 efforts among researchers, practitioners, and policymakers, the optimization of cereal
338 fodder crop management holds great potential for advancing sustainable agriculture and
339 ensuring food security for future generations.

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341

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COMPETING INTERESTS

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350

The authors assert with utmost clarity that they do not possess any competing interests that could potentially sway this study's integrity.

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