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Dactylis glomerata L. (Cock's Foot/Orchard Grass): A Potential Temperate Forage Grass for Cultivation in North Western Himalaya

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Authors' contributions

All the authors contributed in the preparation of this review article. Author NHM conceived the idea, reviewed the literature and wrote the first draft of the manuscript. Authors SA and SSB also managed the literature searches and made necessary corrections and modifications. All authors read and approved the final manuscript.

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ABSTRACT

Animal husbandry is the primary occupation of people inhabiting Himalayan regions, but the forage cultivation has remained almost neglected and restricted to the lower Hills. The majority of the fodder (62%) is extracted from forests (tree, shrub, leaves and herbaceous ground flora) and remaining (38%) is derived from agroforestry systems, low altitude grasslands, degraded lands, high altitude grasslands and crop residues. The unabated exploitation of natural resources of the Himalayas like reckless cutting of trees, indiscriminate use of grazing areas and absence of rehabilitation programmes has led to denudation of hill slopes, which has resulted in critically low biomass availability and adverse effects on livestock productivity. Exploration of alternatives such as cultivation of hardy perennial temperate forage grasses like *Dactylis glomerata* on a range of landforms like within tree-based systems to fallow and sloppy lands etc provide opportunities for forage resource augmentation in the region. Orchard grass (*Dactylis glomerata* L.) is one of the most commonly used forage species and has become naturalized in nearly every continent. It has

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been recognized as an excellent hay, pasture, and silage crop. The present paper discusses the potential and opportunities of *Dactylis glomerata* in Northwestern Himalayan region vis-à-vis fodder resource augmentation.

Keywords: Dactylis glomerata; forage grass; Himalaya; fodder resource augmentation.

1. INTRODUCTION

Though livestock rearing is an important occupation of farmers in North Western Himalayan region, the forage cultivation has remained almost neglected and restricted to the lower Hills. Beyond a certain altitude, the cultivation of fodder is not practical because of adverse climatic and the land constraints. The majority of the fodder (62%) is extracted from forests (tree, shrub, leaves and herbaceous ground flora) and remaining (38%) is derived from agroforestry systems, low altitude grasslands, degraded lands, high altitude grasslands and crop residues [1]. Due to extremes in climate, poor management and constant grazing, all types of grasslands have been degraded and these are found to be less productive [2]. The unabated exploitation of natural resources of the Himalayas like reckless cutting of trees, indiscriminate use of grazing areas and absence of rehabilitation programmes has led to denudation of hill slopes, which has resulted in critically low biomass availability and adverse effects on livestock production. Consequently, the livestock productivity is very low and all the Himalayan states have to import various livestock products from the plains. Forage cultivation is restricted to only about one per cent of the cultivated area in the entire Himalayan region. This is basically because of the preponderance of marginal and small land holdings in the area, climate and land topography. Besides grazing and fodder trees, the major local forage resource is the crop residue, which again is too inadequate to sustain the livestock [3]. In the state like Himachal Pradesh there exists a gap of about 35.0 and 57.0% from dry and green forages, respectively. Every year on an average about 7450 t of wheat straw is imported annually from the neighbouring states [4]. Livestock production is more efficient from cultivated fodder than from the degraded grazing lands but unfortunately, the fodder cultivation has remained static and less than 4% arable land in J&K is under fodder production [5]. The state of Jammu and Kashmir produces around 64 lakh MT of green fodder and 35 lakh MT of dry fodder against a requirement of 139.13 lakh MT and 58.53 lakh MT of green and dry fodder, respectively [6]. Therefore, increased production of fodder is essential to meet the nutritional requirements of the livestock. Further, the agro-climatic condition of the major portion of the region also warrants the need of cultivating even additional fodder that can be dried to hay or stored as silage for lean periods. But a host of factors like growing urbanization and shrinkage of agricultural land, the preponderance of small and marginal farmers, climatic and geographical constraints, social and economic aspects indicate that the chances of expansion of area particularly under annual fodder cultivation are remote. The Northwestern Himalayan region, especially the valley of Kashmir endowed with multiple landforms has a rich diversity of traditional agroforestry models which are in existence since time immemorial [6]. Due to increased population, poor productivity of grassland resource and deficit in forage supply and farmer's inability to spare their cultivated land for forage production, it is essential to utilize the interspaces in these horticultural tree plantations. Among the fruit tree based agroforestry system, the hortipasture systems have been recognized as sustainable land use option because of its high productivity and environmental benefits even under fragile agro-ecosystem [7]. Fruit tree-based land use has been acceptable as a viable alternate land use system [8,9]. Intercropping of perennial forage grasses and/or legumes with fruit crops is fruitful for high forage and fruit production [10]. Rangelands form 55 % of the total area in the Himalayan region and comprise of diverse vegetation types. In J&K, 4.3% of the total geographical area is under productive grasslands whereas the area of other grazing lands including scrub and other unpalatable swards is 9.8% of the total [11]. These areas can be reseeded with perennial grasses and legumes to restore their productivity. *Dactylis glomerata L*. is one of the most important forage grasses in the world owing to its high productivity and disease resistance under varying climatic conditions. It is used for pasture, hay and silage. The main advantage of cocksfoot is greater forage production during summer compared to other forage grasses; it stays green after most prairie grasses have dried [12]. Because of its shade tolerance cocksfoot is

also used in Europe to establish vegetation cover in vineyards or orchards [13]. Due to its overall high forage quality, i.e. sugar and protein contents, shade tolerance and persistence [14] this hardy grass can be raised on a variety of land forms like permanent and temporary fallows, cultivable wastelands, field bunds and risers with minimal inputs. It is drought tolerant, persistent and the main growth period occurs in summer [15]. This temperate grass offers a viable option for cultivation in the North western Himalaya and thus augmenting fodder production in the region.

Fig. 1. Pic of *Dactylis glomerata* L.

2. *Dactylis glomerata* L.- BOTANY AND AGRONOMIC REQUIREMENTS

Cocksfoot (*Dactylis glomerata* L.) is a strongly tufted, deep-rooted, long-lived perennial grass reaching a height of 60-150 cm [16]. Culms are erect and glabrous. Leaf blades are 30-60 cm long and 5-10 mm broad. Inflorescences are erect panicles, 8-20 cm long, bearing spikelets in dense one-sided clusters. The leaves are 2-8 mm wide, and 20-30 cm long, v-shaped near the base tapering to a narrow tip with a prominent mid-nerve on the lower surface. The sheath is closed, auricles absent and the ligule is membranous and often split, merging with the throat margins. The seed is elongate [17,18]. Orchard grass can be diploid (2n=2x=14), tetraploid (2n=4x=28), or hexaploid (2n=6x=42) and are separated into subspecies by chromosome number. Most populations are diploid [19]. It is used for pasture, hay and silage. The main advantage of cocksfoot is greater forage production during summer compared to other forage grasses: it stays green after most prairie grasses have dried [12]. It is found from 0° to 70° latitude but grows better in temperate and sub-tropical regions.

Optimal growth conditions are annual day-temperatures ranging from 4.3°C to 23.8°C, annual rainfall from 480 mm to 750 mm, on normally drained to dry soils, rich soils of heavy types such as clays and loams, with a pH ranging from 4.5 to 8.2 [20]. It is tolerant of shade, high temperatures and drought but does not appreciate excessive humidity [21]. It is one of the earliest grasses to initiate growth in the spring and provides forage during early spring and summer [22]. It produces an extensive root system with rooting depths up to 2 feet. It thrives well under cool, humid, moist or irrigated conditions.

3. FORAGE YIELD AND QUALITY

Cocksfoot is an important perennial grass widely cultivated in temperate regions of the world [23]. Its economic value is based on its high productivity and its disease resistance under varying climatic conditions. Due to its high forage quality, i.e. sugar and protein contents, shade tolerance and persistence it is more suitable for cultivation than many other cool-season perennial grasses and thus the species *D. glomerata* is used for hay or silage production and grazing worldwide [14]. Cocksfoot produces a continuous growth of young leaves and can withstand heavy grazing [24]. It is the most suitable grass under fruit plants in the orchards as it is known to tolerate shade upto 80% without any reduction in the yield. However, legume component may be included with the grass in the orchards. Because of its high shade tolerance, cocksfoot is well- adapted to mixtures with legumes. It is also more competitive with legumes than are other cool-season grasses such as *Bromus inermis* (smooth brome), *Lolium perenne* (perennial rye), or *Poa pratensis* (Kentucky bluegrass) [19]. Because of its shade tolerance cocksfoot is also used in Europe to establish vegetation cover in vineyards or orchards [13]. Numerous cultivars of cocksfoot have been developed for late maturing, higher leafiness, higher productivity, better disease resistance, wider adaptability and nutritive value

[25]. As a cool-season perennial, cocksfoot may be harvested four times a year and remains productive during 4 to 8 years. It was found that N @240-360 kg/ha fertilized cocksfoot could be harvested four times per vegetation season [26]. Hay yields may be up to 13.5 t/ha with adequate fertilizer and up to 5-6 t/ha with no additional fertilizer. The fertilization with higher nitrogen rate had a positive effect on cocksfoot biomass yield of swards, which were harvested for the first time at heading stage [27]. Cocksfoot is tolerant of shade and is an ideal companion grass for legumes in mixed permanent pastures [28]. It is suitable for mixed sowing with alfalfa (*Medicago sativa* L.) or red clover (*Trifolium pratense* L.) for hay or white clover (*Trifolium repens* L.) for grazing [13]. Moreover, it acts as a good cover crop and prevents weed growth in orchards leading to better floor management. In the pastures, if controlled or rotational grazing is followed, best production, persistence, and fodder quality is obtained. Heavy grazing during October can lead to depleted root reserves and increased winter injury. This plant responds well to rotational-deferred grazing systems. Periodically the grass should be allowed to mature and produce seed for the continuation of the stand [22], if harvested in spring during boot stage, the produce is of highest-quality forage and high-yielding hay. Beyond this stage, there is little increase in yield and the digestibility decreases at the rate of about 0.5 percent per day. Aftermath growth can be harvested at 4 to 6-week intervals. Production and cutting frequency are greatly affected by soil moisture, soil temperature, soil fertility, and disease incidence [29] if cocksfoot is harvested late each year, the stand will become thin and bunchy. The forage should be cut 5-7 cm above the ground for rapid regeneration of growth. Cocksfoot is considered to have low palatability [15,30,31, 32,33]. This reduces animal production because of reduced voluntary intake. However, it has been shown that crude protein (CP) content of the herbage on offer can influence grazing preference [34]. Annual DM yields of cocksfoot, in Canterbury, range from 7 to >28 t DM/ha [35], [36]. The lower value represents a typical yield under grazed dryland conditions and the upper extreme was considered the environmental maximum when neither water nor nitrogen limited pasture growth. The green fodder yield of 22.32 t/ha and dry fodder yield of 7.39 t/ha in cocksfoot was obtained in an apple based hortipastoral system under temperate conditions of Kashmir [37]. The average dry matter yield of both native and exotic grasses varies considerably from 2.5 t/ha in *Agrostis* spp. to 10.0 t/ha in *Dactylis glomerata* in Kashmir Himalaya [38]. The crude protein content is also better than many oat varieties and varies from 28.3% at pre-joint to 12.5 % at the late bloom stages [29]. Cocksfoot responds very well to good fertility management. It is one of the most responsive pasture grasses to nitrogen applications [22]. One strategy to even out the forage production is to fertilize the stand after the first and second cutting or grazing period to boost late spring and summer production. However, good produce can be obtained even with the low input like fertilizer and organic manure usage. As a hay crop, it should be cut at first bloom because older stems become coarse and unpalatable afterwards. Since cocksfoot is a high-quality grass, it can be grazed by most classes of livestock [22]. Cocksfoot (*Dactylis glomerata*) is the major dryland pasture grass used in countries like New Zealand. It is drought tolerant, persistent and the main growth period occurs in summer [15]. In Canterbury reported annual yields range from 7.5 t DM/ha to 28.6 t DM/ha. The lower yield indicates an average year with no N and dryland conditions [35] whereas the high yield [36] was produced under non-limiting water and N conditions. Cocksfoot can dominate white clover in mixed swards [39] to the point where pasture quality declines, as the vegetation becomes protein deficient [31]. It has been shown that N fertility status of pastures affects grazing preference [34]. This is particularly important for cocksfoot pastures which have been shown to be N deficient throughout the year. Furthermore, dryland cocksfoot pastures supplied with adequate N produced 80% more yield annually than pastures supplied with irrigation alone [36]. Cocksfoot is one of the richest temperate grasses as measured by protein content. In Western Europe, protein content is usually between 15-20% DM, although 25% protein is possible in young cocksfoot grass [39]. However, values higher than 30% protein have been observed in New Zealand [34]. The protein content declines with maturity and can be lower than 10% DM at the end of flowering. This high protein content is counterbalanced by a fibre content (crude fibre 25-30% DM) that is often higher than that of other grasses (notably ryegrass and fescue) at the same stage of maturity stage [39]. Cocksfoot is very valuable for pasture, silage and hay in humid temperate climates. Re-growth is abundant in autumn, which allows for a lengthier grazing period and therefore for more-profitable milk and meat production. Orchard grass has been reported as

one of the most tolerant grass species in temperate agroforestry systems. Overall benefits from the integration of forage species in agroforestry systems include facilitation of mutual growth of tree and hay crops, potential revenue from dual crops, and increased carbon storage from grass and legume species [40]. For example balanced cocksfoot dairy rations can be well utilized by lactating dairy cattle, resulting in higher yields than alfalfa, provided that grass is harvested at an appropriate stage resulting in higher yield and quality [41]. Cocksfoot has to be cut at flowering stage to ensure it is nutritious (high protein content), and also to promote growth of palatable tillers [42].

Cocksfoot is free of alkaloids and mycotoxins [43]. The association of cocksfoot with alfalfa can help to reduce the incidence of bloat. In steers, for example, the presence of 25 to 50% cocksfoot in an alfalfa pasture reduced frothy bloat by 70 to 90% [44]). Cocksfoot is a lesser magnesium accumulator than other grasses, notably fescue and is therefore more prone to be associated with grass tetany or hypomagnesaemia [45,46].

Cocksfoot is often the grass of reference in ruminant feeding trials in temperate countries [16]. Cocksfoot is sometimes described as being highly palatable [47]. For instance, in palatability trials carried out in the USA in the 1950s, it was the most relished grass when grazed by cows in pastures sown with other grasses such as fescue, *Poa pratensis*, timothy or brome grass [48]. In more recent trials in New Zealand, grazing calves preferred orchard grass (cocksfoot) over timothy, fescue, ryegrass and legumes [49], high-protein cocksfoot was found to be as palatable as other grasses [34]. However, other observations are less positive and cocksfoot has been found to be of low or moderate palatability. These variations can be explained by the protein content or by the variety [50,51,52]. In grazing sheep, cocksfoot intake rose with increasing levels of nitrogen fertilizer [50,53]. Animals can adapt their intake to grazing conditions: in Argentina, heifers grazing mature cocksfoot re-growths used shorter grazing times and shorter bite rates, resulting in larger intakes [54].

Mills [52] in 2007 reported ME values of 10.2-12.4 MJ/kg for cocksfoot pasture. The ME was lower in late spring and summer compared to autumn and winter. The digestibility of protein is influenced positively by the level of additional fertilizer [50]. *In sacco* N degradability in fresh cocksfoot decreases with the age of the forage from 69% at heading to 59% at flowering. It was higher for silages (70-77%) and lower for hay (53%) harvested at the same stage [55].

Table 1. Crude protein and DDM at different stages [29]

Stage	Crude protein (%)	Digestible dry matter (%)
Pre joint	28.3	82
Early head	16.8	66
Early bloom	14.7	63
Late bloom	12.5	57

4. CULTIVATION OPPORTUNITIES IN NORTH WESTERN HIMALAYAN ZONE

The North western Himalayan states of J&K, HP and Uttarakhand have great diversity in the geo-ecological conditions, which suit ideally to the cultivation of almost all kinds of temperate and most of the varieties of tropical and sub-tropical fruits. The Valley of Kashmir being in higher latitudes and altitudes generally grows numerous varieties of apples, apricots, almonds, peaches, cherries, plums, pears, walnuts, melons and grapes. The farmers are increasingly concentrating on fruit cultivation and more area is being brought under orchards. According to the J&K State Horticulture Department, the area under horticultural crops in J&K was 3.57 lakh hectares in 2015-16. Similarly in the state of Himachal Pradesh, the area under horticulture was 224352 Hectares in 2014-15 [56] and 171.6 thousand hectares in Uttarakhand [57]. This vast area provides for ample opportunities for incorporation of pasture component like orchard grass in these plantations. The perennial forage grasses like Cocksfoot have great scope for cultivation under various landforms like meadows, grasslands, deteriorating grazing lands, cultivable wastelands, field bunds and risers etc owing to its hardy nature. Cocksfoot is a major pasture grass used in dry land pastoral environments in New Zealand. It is recommended for use in both flat dry land and hill country systems because of its moderate fertility requirement, persistence and drought tolerance [15,58]. Further, reportedly animal health problems associated with feeding of other grasses like perennial ryegrass, low nutrition crops and weeds are avoided because no harmful alkaloids are produced. Although annual fodder crops, grasses and weeds from cultivated fields provide green nutritious fodder for a few

months of the year, perennial grasses like cocksfoot can provide green nutritious fodder for an extended period of time as two to three cuts are possible in a year. Orchard grass is primarily a pasture grass. However, it is very suitable for silage and stall feeding hence may provide good quality feed during the otherwise lean period in the Himalayan region. Stevens and Hickey in 2000 reported peak production from a cocksfoot pasture occurred four years after establishment but measurements ceased after the fourth year [59]. Seasonal production is generally lower than ryegrass in spring but this is offset by increased production in summer and autumn [58]. In Canterbury, total annual DM production of dry land cocksfoot was 7.6 t DM/ha compared with 4.9 t DM/ha from ryegrass pastures [35]. In contrast, under non limiting conditions in Canterbury, a 10 year old cocksfoot dominant pasture was shown to produce a potential maximum yield of 28.6 t DM/ha/y [36]. Sowing period in cocksfoot is long and extended and can be either done in fall (autumn) or spring. For autumn, sowing can be done from 15th September to 15th December. During this period most of other agricultural activities are suspended in the hilly areas due to the onset of cold winter. For spring, sowing should be done in March. In case of non-availability of irrigation facilities, it can be grown on residual moisture in the soil at the time of sowing. Cocksfoot roots form a dense fibrous mat in the top 0.25 m of the profile [60,61]. Evans measured 16.0 m of cocksfoot roots in the top 0.20 m of the soil compared with 3.3 m in ryegrass or white clover treatments [62]. The production of a more extensive root system increases the surface area for water and nutrient uptake. The North western hilly zones are highly prone to various forms of land degradation. About 32% area of J&K is affected by various soil degradation problems. Average soil loss in J&K is 20 tonnes/ha/year which is higher than the national average loss of 16.37 tonnes/ha/year [63]. In HP state about 27% area has soil loss > 15 t ha^{-1} and varies in intensity from moderately severe (15-20 t ha^{-1}) to extremely severe (>80 t ha^{-1}) [64]. Among agronomic interventions planting of Dactylis grass can be an important component of sloppy agricultural land technology (SALT). Because of its dense network of non-rhizomatous roots, it provides good erosion control on sites where it is adapted. It is recommended for erosion control on forestland that has been burned or logged, often showing early establishment and eventually being replaced by native vegetation or other seeded species [65]. It may also be used as a ground cover, in order to control soil erosion and for lawns or ornamental borders [20]. As a deep-rooted perennial grass, cocksfoot is an excellent ground cover and may be used in rehabilitation programmes: for example soil erosion control on cut-over forest land or on slopes, and rehabilitation of sites disturbed by mining [66]. Once established it may be cultivated without additional fertilizer and without pesticides [27]. However, it is preferred by livestock when grown with adequate plant nutrients [48].

The climatic requirements of Cocksfoot are very much in accordance with the North Western Himalayan climate. In field-grown cocksfoot, leaf photosynthesis was optimum between 19-23°C [36]. This was comparable to the 20-22°C optimum range reported in controlled environments [67,68]. Every 1°C drop below 19^{o}C caused the rate of photosynthesis to decline by 6% from the maximum of 27.4 µmol $CO_2/m^2/s$ [36]. When temperatures exceeded 23°C, photosynthesis also declined but at a rate of 8%/°C. The significance of orchard grass cultivation on nutrient recycling and climate change mitigation has been well advocated. Cocksfoot can use high rates of Nitrogen (N) when grown on deep soils with adequate water supplies, making it valuable in nutrient recycling systems. It can be used in manure and bio-solid applications to recycle large amounts of N (in excess of 300 pounds N/ac/yr) while simultaneously producing high-quality forage [65]. Genetic improvement efforts in forage crops have been very limited except for the coarse cereals and minor millets used both as forage and fodder and the temperate crops of European and Central Asian origin. The major yield gains in most other crops have been achieved by improving the agronomy and the cultural practices. A great scope exists to increase forage productivity by diversifying the crop base, strengthening the genetic improvement activities, including utilizing the wild relatives of cultivated species. In this regard, efforts are needed for collection, characterization, evaluation, cultivation and conservation of new/wild forage species. Natural populations of *D. glomerata* are of major importance for forage crop breeding. In natural and semi-natural grasslands, those populations harbour high genetic diversity, which provides advantages for future breeding and conservation programs in particular with respect to climatic changes and an increasing demand for forage and food production [69].

5. CONCLUSION

With the burgeoning population, growing industrialization and urbanization there is an increased demand for the livestock products mainly meat and milk. The Himalayan region is generally deficient in adequate quantities of quality fodder, being one of the important factors for low livestock productivity. With deteriorating grazing lands and dwindling chances of area expansion under annual fodder cultivation, alternative crops which are hardy, can tolerate fair amounts of shade, drought and cold stress and can be grown in a variety of landforms with minimal inputs and management and are perennial (can provide green nutritious fodder for extended period of time) besides being helpful in soil conservation need to be identified and cultivated. Cocksfoot is one such crop that seems a promising option given its great potential as a cool-season pasture grass.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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