Seed Yield and Quality of Italian Ryegrass as Affected by Harvesting Date

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Summary

There is a lack of applied research in Croatia on optimum harvesting date in Italian ryegrass (*Lolium multiflorum* Lam.) crop for maximizing seed yield and seed quality. Thus, seed yield, yield components, and seed quality were determined for Italian ryegrass crop from the primary growth (pure-seed crop) and from the regrowth after first cut for forage (forage-seed crop). Both crops were harvested at early-, mid-, and late harvesting dates that were 19, 24 and 29 Jun in the pure-seed crop and 3, 6 and 10 July in the forage-seed crop. In spite of significantly lower density of fertile tillers (ears), average seed yield was significantly higher in the pure-seed than in the forage-seed crop. Both crops had similar ear length and floret site utilization, but ears from the pure-seed crop had more spikelets per ear, florets per spikelet as well as heavier seed weight than those from the forage-seed crop. Maximized seed yields were produced at mid-harvesting dates for both crops when seed moisture was 44.1% for the pure-seed crop (552 growing degree days following anthesis) and 40.4% for the forage-seed crop (505 growing degree days following anthesis). Depending on crop management and harvesting date, seed moisture loss ranged from 1.2% to 3.6% per day. Seed germination was not affected by crop management or by harvesting date despite differences in 1000-seed weight. In conclusion, harvesting crop with seed moisture content around 40-45% maximized seed yields for the pure-seed as well as the forage-seed crop, while harvesting date had no effect on seed germination.

Key words

Italian ryegrass, seed yield, yield components, moisture content, germination

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Introduction

Italian ryegrass (*Lolium multiflorum* Lam.) is the most common grass species grown for forage and seed production in Croatia. It is grown on dairy farms as forage crop or in a combined forage-seed system. For the latter, one or more forage cuts in the spring are followed by the seed crop harvested in summer.

Seed grower has to contend with a crop where the inflorescence will be at different stages of ripening at harvest (Wilson, 1959). The greatest weight of seeds is yielded by the longer inflorescences born on the older tillers (Ryle, 1966) and it is the best to harvest when the majority of these are ripe rather than waiting for the later shorter inflorescences to mature. Seed is usually doughly when ripe and the green color is beginning to fade (Hyde et al., 1959), while the stem also begins to yellow. At this stage loss can be rapid so that frequent checks are necessary. Moisture content can be expected to fall by 1 to 3% per day in good conditions (Raja Harun and Bean, 1979).

It is possible to take Italian ryegrass seed crop without spring defoliation, but there are two disadvantages: more lodging may occur before anthesis and there may be excessive vegetative regrowth to deal at harvest. The adverse effect of lodging on seed yield may be attributed to reduced photoassimilate supply to developing seeds (Clemence and Hebblethwaite, 1984), limited pollination (Wright and Hebblethwaite 1979), and low set seed (Burbidge et al., 1978). The incidence of lodging in a combined forage-seed system for Italian ryegrass crop may be lowered by using first-cut for forage. Brown (1980) stated that one of the main causes of lodging is over-vigorous vegetative growth that, if left ungrazed, allows crops to become too leafy, too long and with stems too weak to bear the load of inflorescences when exposed to strong winds and/or heavy rain. Defoliation mitigates against these possibilities and has the added advantage that the value of grazing or cutting offsets some of the costs of growing crop. Defoliation should not take place when field is excessively wet and there is danger of poaching.

The proper time of harvesting is essential for the production of the maximum quantity of high-quality seeds (Silberstein et al., 2006). Seed moisture is the most common indicator for determing when harvesting is to be done for seed commercial crop (Silberstein et al., 2010). Since grass seed crop do not pollinate and mature over a uniform time period, there is a wide range of seed maturity within a crop stand. Harvesting too early at high moisture content shortens the seed fill period and can cause reduced seed size and increase the number of immature seed, while harvesting too late at low moisture content can decrease seed yield through losses due to seed shattering (Klein and Harmond, 1971; Andersen and Andersen, 1980). Italian ryegrass is particularly vulnerable to seed shedding and is, therefore, generally direct combined at higher moisture content than perennial ryegrass (Gwynne, 1973). The mechanism behind seed shedding is not clear. Although the study of Raja Harun and Bean (1979) have shown that reducing seed shedding losses in material of north Italian origin is likely to be through a reduction in the moisture content at which seed shedding begins rather than the rate that it proceeds thereafter. Glasshouse test by Hides el al. (1993) showed that artificially induced shedding losses of two cultivars of Italian ryegrass began at a relatively similar moisture content of around 48%, after which shedding proceeded at the same rate for the both cultivars.

There is limited information on what would be the optimum harvesting date in ryegrass crop for maximizing seed yield and seed quality. Therefore, the main objective was to study the effect of harvesting date on seed yield, yield components and seed quality of Italian ryegrass grown under various crop managements.

Materials and methods

Field experiment was conducted in north-western Croatia at the Faculty of Agriculture Zagreb experimental field during the 2011/12 growing seasons on a silt loam soil (Typic Udifluvents) with winter wheat (*Triticum aestivum* L.) as a proceeding crop. Soil was plowed to a depth of 25 cm and then prepared for seedbed to a depth of 10 cm. Tetraploid Italian ryegrass cv. Mir was sown in 20-cm rows with a small plot drill (Wintersteiger, Ried im Innkreis, Austria). At seeding, individual plots consisted of 12 rows 6.0 m in length. Crop was planted at 450 seeds m^{-2} on 3 November 2011. Granular nitrogen (ammonium nitrate, 27%) was hand broadcast in each top-dressing application. First top-dressing with 90 kg N ha^{-1} was on 5 March 2012 when crop was at GS 13-14 (Zadoks et al., 1974) and second top-dressing with 90 kg N ha^{-1} was on 4 May 2012 (GS 32-33).

First investigated factor consisted of Italian ryegrass crop from the primary growth (pure-seed crop) and crop where seed was harvested from the regrowth after first cut for forage (forage-seed crop). Forage cut for the forage-seed crop was on 18 May 2012 when crop was at GS 45-49. The second factor in this study was various harvesting dates, which were based on growing degree days following anthesis (Griffith and Chastian, 1997). Growing degree days were calculated from the data of weather station located 300 m from the experimental site using a base temperature of 0°C. Summary of harvesting dates for Italian ryegrass crops is presented in Table 1.

Seed yields were harvested in the first production year after establishment. The six 30-cm sections in the row of each plot were clipped at ground level at each harvest date to determine the density of fertile (productive) tillers (ears). At all harvesting dates plants were clipped during morning hours with minimal disturbance to maximally prevent shattering of seed from ears. Thirty productive tillers were randomly selected to determine seed moisture and yield

Table 1. Harvesting dates for Italian ryegrass grown as the pure-seed and the forage-seed crop

Crop management	Full anthesis	Harvesting date	Date	Growing degree days after anthesis (°C)	Precipitation after anthesis (mm)	Days after anthesis (no.)
Pure-seed crop	29 May	Early-	19 Jun	423	110	21
		Mid-	24 Jun	552	110	26
		Late-	29 Jun	662	130	31
Forage-seed crop	16 Jun	Early-	3 July	422	20	17
		Mid-	6 July	505	20	20
		Late-	10 July	615	20	24

components. Fifteen ears (inflorescences) were used to determine ear length, spikelet number per ear, floret number per spikelet, and seed number per spikelet. The spikelets analysed for floret and seed number were positioned in the middle of the basal, central, and apical positions of the ear. The mean number of florets per spikelet was calculated from those three spikelets at different positions within ear. Floret site utilisation represents the percentage of the florets containing the developed seeds. Very late ears that had not set seeds yet were excluded from analysis. The remaining 15 ears were hand-threshed, cleaned, weighed and the 1000-seed weight determined. The moisture content of ryegrass seed was determined in subsample and the seed yield per unit area was adjusted to 14% seed moisture. A subsample of hand-thrashed seed was dried at room temperature for germination tests, which started two weeks after each harvest date. Germination was determined according to the ISTA Rules (ISTA, 2008) by placing 100 seeds to imbibe on a moist germination/filter paper. After a chilling treatment for five days at 5°C, the seeds were germinated at 20°C. The final seedling count was made after 14 days.

Field trail was arranged in a split-plot design with four replicates. The pure-seed crop and the forage-seed crop were randomized to the main plots within replicates. Harvesting date was assigned to the sub-plots. Data were analysed using Mixed Model procedures (SAS Institute, 1997). Analysis of variance was computed with crop and harvest date considered fixed. Means separation was calculated using the LSD values if the F-test was significant at $P \leq 0.05$.

Results and discussion

Although both the pure-seed and the forage-seed crops accumulated similar amount of growing degree days at early-harvesting date (Table 1), the duration of anthesis to early-harvesting date period was shortened by four days for the latter. This was primarily due to higher air temperatures, which averaged 24.8°C for the forage-seed crop compared to 20.2°C for the pure-seed crop. Even larger differences in growing degree days accumulation and days following anthesis to harvest were found for the later harvesting dates. Growing degree days were around 50°C lower at mid- and late-harvesting date, while the duration of anthesis to harvesting date period additionally shortened for the forage-seed crop in comparison to the pure-seed crop. This was mainly due to higher air temperatures during anthesis to harvest period for the forage-seed crop that matured later in the growing season (in July) compared to the pure-seed crop (in June) (Figure 1). Air temperatures averaged 21.4°C for the pure-seed crop and 25.6°C for the forage-seed crop during the anthesis to late-harvesting date period.

Compared to the pure-seed crop, seed moisture for the forage-seed crop was lower at all harvesting dates (Figure 2), which was mainly associated with higher air temperatures and partly due to less rainfall during the anthesis to harvest period (Figure 1). As expected, seed moisture content was the highest at early-harvesting date in both the pure-seed and the forage-seed crops and the lowest at late-harvesting date. Over a 10-day period between early- and late-harvesting dates, seed moisture declined from 51.4% to 37.9% for the pure-seed crop (Figure 2), averaging in 1.3% daily moisture loss. For the forage-seed crop, moisture content over a 7-day period between early- and late-harvesting dates declined from 49.0% to 25.9%, averaging in a rate of 3.3% per day. In a glasshouse experiment by Raja Harun and Bean (1979), the moisture content of the seeds of populations of Italian ryegrass decreased linearly with

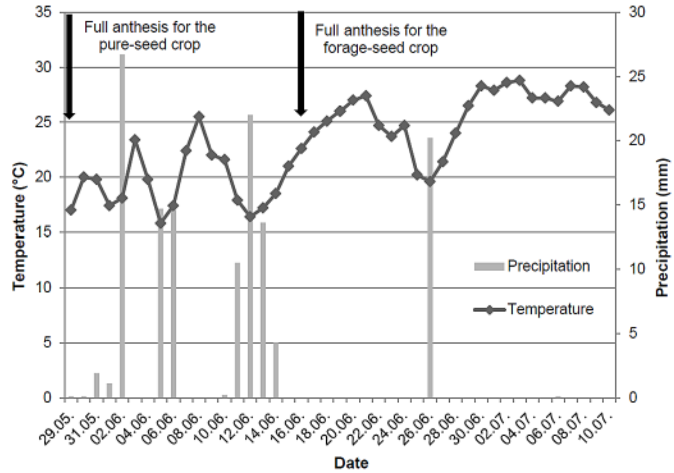

Figure 1. Mean daily air temperature and precipitation during the post-flowering period of various Italian ryegrass crops

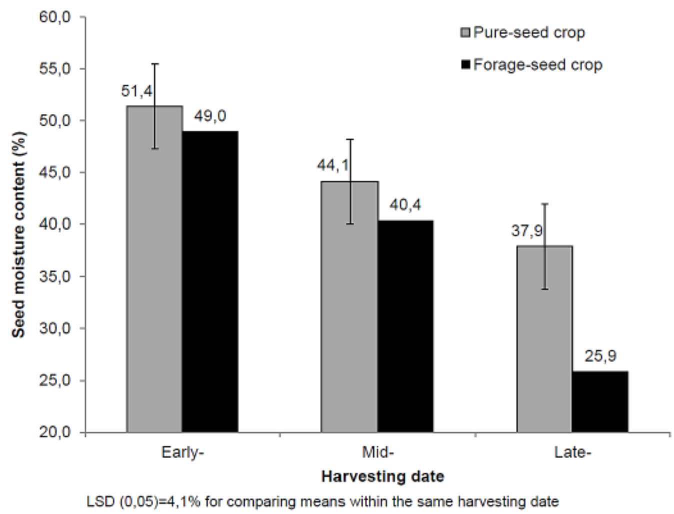

Figure 2. Effect of harvesting date on seed moisture content of Italian ryegrass in the pure-seed and the forage-seed crop

time at an approximately rate of 1.0% per day. In our experiment, the lowest (1.2%) and the highest (3.6%) daily moisture loss were calculated between mid-and late-harvesting dates in the pure-seed and the forage-seed crop. A significant crop management × harvesting date interaction for seed moisture content existed (Table 2). Seed moisture contents were similar at early- and mid-harvesting dates in both crops, whereas the forage-seed crop had significantly lower seed moisture than the pure-seed crop at late-harvesting date (Figure 2).

Seed yields were significantly affected by crop management (Table 2). The pure-seed crop achieved higher seed yields despite significantly lower density of fertile tillers (ears) compared to the forage-seed crop (Table 3). Brown (1980) found that grazed crops had larger tiller populations than ungrazed crops but seed yields of Italian ryegrass were similar under both managements. In our research, ear length averaged 26.4 cm for the pure-seed crop, which was slightly longer than 25.8 cm for the forage-seed crop. However,

Table 2. Analysis of variance for seed moisture content, seed yield, yield components and seed germination of Italian ryegrass

Source of variation	df	Seed moisture content	Seed yield	Ears per square meter	Ear length	Spikelets per ear	Florets per spikelet	Floret site utilization	1000-seed weight	Seed germination
Rep	3	—	—	—	—	—	—	—	—	—
Crop (C)	1	*	*	**	NS	*	*	NS	*	NS
Error a	3	—	—	—	—	—	—	—	—	—
Harvest date (HD)	2	**	*	NS	NS	NS	NS	NS	NS	NS
Error b	6	—	—	—	—	—	—	—	—	—
C × HD	2	*	NS	NS	NS	NS	NS	NS	NS	NS
Error c	6	—	—	—	—	—	—	—	—	—

* - significant at P = 0.05 level, ** - significant at P = 0.01 level, NS - not significant.

Table 3. Effect of crop management on average seed yield, yield components and seed germination of Italian ryegrass

Crop management	Seed yield (kg ha^{-1})	Ears per square meter (no.)	Spikelets per ear (no.)	Florets per spikelet (no.)	1000-seed weight (g)	Seed germination (%)
Pure-seed crop	1664*	541	25.6*	9.3*	3.79*	93.2 NS
Forage-seed crop	1321	694**	21.5	7.8	3.30	91.9

* - significant at P = 0.05 level, ** - significant at P = 0.01 level, NS - not significant.

Table 4. Effect of harvesting date on average seed yield, yield components and seed germination of Italian ryegrass

Harvesting date	Seed yield (kg ha^{-1})	Ears per square meter (no.)	Spikelets per ear (no.)	Florets per spikelet (no.)	1000-seed weight (g)	Seed germination (%)
Early-	1536a§	605a	24.3a	8.6a	3.41a	94.0a
Mid-	1616a	616a	24.8a	8.5a	3.57a	92.8a
Late-	1327b	633a	24.6a	8.6a	3.67a	90.9a

§ Values followed by the same letter in each column are not significantly different based on the LSD test at P ≤ 0.05 level.

significantly more spikelets were found for the pure-seed crop (25.6 on average) compared to the forage-seed crop (21.5 on average), indicating that spikelets were more compacted within ear in the pure-seed crop. In addition, ears from the pure-seed crop had more florets per spikelet as well as heavier seed weight than those from the forage-seed crop (Table 3). The difference in 1000-seed weight was mainly due to less favourable weather conditions (higher temperatures and less rainfall) for the forage-seed crop, which in turn, resulted in shorter seed filling period expressed in days. Herron (1976) reported a decrease in spike length, spikelets pre spike, florets per spikelet and seed weight when Italian ryegrass crop grazing was extended from mid-April to early May in Oregon. Floret site utilization was not affected by crop management (Table 2) and averaged 68.7% in the pure-seed crop, and 71.6 % in the forage-seed crop. For perennial ryegrass (*Lolium perenne* L.), Burbidge et al. (1978) reported that the percentage of florets that set seed reached a maximum value of about 60%.

Although harvesting date had no effect on yield components (Table 2), significant differences in seed yield existed. Maximized seed yields were produced at mid-harvesting date when seed moisture was 44.1% for the pure-seed crop (552 growing degree days following anthesis) and 40.4% for the forage-seed crop (505 growing degree days following anthesis). Compared to earlier harvesting date, the yield increments at mid-harvesting date were mainly associated with slightly heavier 1000-seed weight and slightly more ears per square meter (Table 4). Findings of Silberstein et al. (2010) also indicate that maximum seed yield of Italian ryegrass was achieved when seed moisture was about 40 to 45%. Direct combining is not usually advisable at moisture content above 40.0%, but authors such as Raja Harun and Bean (1979) reported that seed crops of Italian ryegrass may be successfully direct combined at 45.0% moisture content. Slightly lower seed yields occurred at early-harvesting date, whereas seed yields were significantly reduced at late- harvesting date (Table 4).

The absence of crop management × harvesting date interaction (Table 2) indicated that yield reductions at late-harvesting date were similar for both the pure-seed and the forage-seed crops. Since the 1000-seed weight consistently increased with later harvesting dates, these yield reductions were presumably associated with seed shattering. It is well-known that the undesirable feature of Italian ryegrass is its inability to retain seeds until the time of harvest and the percentage seed shed by weight increases significantly with time. Therefore, Italian ryegrass is generally direct combined at higher moisture content than perennial ryegrass (Gwynne, 1973). Raja Harun and Bean (1979) reported that seed shedding in Italian ryegrass may start as early as 24 days after anthesis, while the 1000-seed weight is still increasing (until approximately 27-30 days after anthesis). In our experiment, the 1000-seed weight tended to increase with later harvesting dates (Table 4). Hides et al. (1993) reported that the 1000-seed weight increased up to 32 days after anthesis, while Hyde et al. (1959) found increased 1000-seed weight up to 28 days following anthesis. Increased 1000-seed weight of retained seeds on ears at later harvesting dates could be also associated with seed shedding from top of the ear that are lighter than seed from the base of the ear. However, Silberstein et al. (2010) clearly indicated that larger seeds retained on ears cannot compensate for yield losses due to seed shattering.

In spite of observed differences in 1000-seed weight across investigated factors (Tables 3 and 4), seed germination was not affected by crop management or by harvesting date (Table 2) and averaged 92.6%. In Oregon, Young et al. (1996) found that seed germination of annual ryegrass (*Lolium multiflorum*) ranged from 86 to 97%. Simić et al. (2010) reported that crop management had no effect on seed quality although germination ranged greatly across various environmental conditions. Our results indicated that satisfactory seed germination of Italian ryegrass may be achieved across various harvesting dates and crop management practices, allowing greater flexibility in harvesting for Croatian farmers. Satisfactory seed germination was found even at earlier harvesting date when seeds have not yet achieved maximum seed weight. Similar results were previously reported by Raja Harun and Bean (1979) who found that maximum germination values were reached at about 26 days after anthesis. However, Hampton (1986) reported that increasing 1000-seed weight improved seedling growth, emergence at 5 and 10°C, and seed vigor of tetraploid Italian ryegrass. In addition, author reported that the dry matter production from the large seeds was significantly larger than from the small seeds in the early crop stages.

Conclusions

Seed yield of Italian ryegrass was significantly higher in the pure-seed crop compared to the forage-seed crop although the latter had more productive ears per unit area. Ear length and floret site utilization was similar for both crops, but more spikelets per ear, more florets per spikelet, and heavier seed weight were found on ears from the pure-seed crop. Crop accumulated around 420 growing degree days following anthesis at early-harvesting date. Seed moisture loss ranged from 1.2% to relatively high 3.6% per day varying on crop management and harvesting date. Seed yields maximized at mid-harvesting dates with seed moisture of 44.1% for the pure-seed crop and 40.4% for the forage-seed crop, when around 550 and 500 growing degree days were accumulated after anthesis, respectively. Seed germination was not affected by crop management or by harvesting date despite of observed large differences in 1000-seed weight and seed moisture content at harvest, and it averaged 92.6%.

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