Mixtures of whipgrass with cool-season annual forages to extend the forage production season in south-west China

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Abstract

Whipgrass (*Hemarthria compressa*) cv. Guang yi is commonly grown in south-western China as forage for livestock but production during the late autumn-early spring period is limited. The objective of this study was to determine if oversowing small grains or ryegrass into whipgrass swards could extend the production season for the pasture, especially in late autumn and early spring. The study was conducted from 2005 to 2007 in Ya'an, Sichuan Province, China. Triticale (*Triticosecale* spp.) cv. Zhongsi 828, rye (*Secale cereale*) cv. Dongmu 70 and annual ryegrass (*Lolium multiflorum*) cv. Changjiang No 2 were broadcast in early September into whipgrass swards, which had been cut and disced. In late autumn （Harvest 1）, forage yields of all mixtures were 1.62 t/ha higher on average than that of whipgrass monoculture (yield 0.19 t/ha). In spring (Harvests 2–4), mixtures of whipgrass with annual ryegrass, triticale and rye produced 12.51, 10.67 and 10.16 t/ha, respectively, compared with 2.76 t/ha for whipgrass monoculture. The mixtures contained less than 40% whipgrass. Highest crude protein concentrations in autumn (186 g/kg) and spring (122–146 g/kg) were in pure whipgrass and the whipgrass-ryegrass mixture. In summer, virtually all available forage on all treatments was whipgrass, with yields in excess of 20 t/ha and crude protein concentration of 78 g/kg. This study suggests that ryegrass, triticale and rye can be successfully sown into whipgrass swards in autumn without the use of herbicides, to increase autumn-spring and total season forage production in the following year.

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Introduction

Warm-season grasses are the major forage resource for ruminant livestock production in tropical and subtropical areas of the world. With the C_4 photosynthetic system, they are well adapted and yield well under warm conditions. In addition, many warm-season grasses are well adapted to temperate areas, where there are relatively long, hot periods during the summer (Belesky and Fedders 1995; Moser *et al*. 2004). However, these grasses have two major shortcomings (Moser *et al*. 2004). They are generally not high in quality, except early in the warm season, and are green only during the summer. However, these deficiencies can be overcome by oversowing cool-season annuals such as small grains, annual ryegrass and legumes into warm-season perennial grasses in autumn to achieve a year-round growing season (Evers 1985; Moyer and Coffey 2000). The cool-season forages have a higher nutritive value than warm-season grasses and provide winter–spring grazing, reducing the need for stored forages and improving animal performance (Fribourg and Overton 1973; Moser *et al*. 1996; Botha *et al.* 2008). In addition, they provide spring weed control (Evers 1983), and in the case of legumes, add nitrogen to the pasture system (Dunavin 1982). Oversowing into a warm-season perennial grass pasture avoids erosion, since there is no deep tillage and no exposed bare soil (Sistani and McLaughlin 2006). This pasture system makes efficient use of animal manure application, since there is year-round nutrient uptake (Sistani *et al.* 2008). In autumn and late spring, the growing seasons of the warm-season perennial grasses and the cool-season annuals overlap. In autumn, it is especially difficult for a cool-season annual seedling to compete with a well established warm-season perennial grass (Utley *et al*. 1976). Periods of hot and/or dry weather during this time also present a challenge for establishment of cool-season annuals. There is a need to explore appropriate management strategies to ensure successful establishment of cool-season annuals when oversown into warm-season perennial grass pastures.

Whipgrass (*Hemarthria compressa*) is a warm-season perennial, which is widely grown for summer grazing and hay production in south-western China (BICSS 1997; Yang and Zhang 2006). It can be harvested from early summer until autumn and is often used in summer forage production (Gu and Hong 1991). It produces few seeds, and is vegetatively propagated, spreading rapidly from prostrate stolons, which root easily at the nodes and produce new shoots (Yang and Zhang 2006).

A number of whipgrass selections have been made since 1956, and two lines were released in 1986 as cvv. Guang yi and Chong gao (Yang *et al*. 2004a). Production and harvesting of these cultivars in south-western China is restricted to the warm summer months (He and Huang 1992; Wu and Du 1992). Annual forage dry matter (DM) production and nutrient concentration in whipgrass-based systems could be improved by extending the forage production season. Double-cropping warm-season whipgrass with cool-season annual forages is an option, which has been explored in forage systems in south-western China (Yang *et al*. 2004b; He *et al*. 2006). Oversowing cool-season annual forages into dormant whipgrass in autumn could increase winter ground cover and provide earlier spring growth than whipgrass alone.

The objective of this research was to determine if oversowing small grains or Italian ryegrass into whipgrass swards in early autumn had the potential to increase autumn or spring production of high-quality forage.

Materials and methods

The study was conducted from 2005 to 2007 at the Research Center of Sichuan Agricultural University, Ya'an, Sichuan Province, China (38°08′ N, 103°14′ E; 600 m asl), which lies in the South-transitional Zone. While the average temperature is 16.2℃, winter lows of -10 to -15℃ are not uncommon and summer highs of 37.7℃ have been recorded. The average annual precipitation is 1774 mm. Experimental plots were located in a whipgrass sward cv. Guang yi that had received applications of swine lagoon effluent. Soil at the site was a sandy-clay-loam (23.8% clay, 14.7% silt, 61.5% sand) with pH of 6.4 and 2.8% organic matter. The whipgrass had been established from sprigs in 2002, and effluent had been applied during May–October each year beginning in 2002. Rainfall and temperature records in the vicinity were obtained from Dynemet Weather Station for Evapotranspiration Models (Dynamax Co., USA) during the study (Figure 1).

Experimental plots were 2 m × 5 m and were separated and surrounded by 0.5 m alleys and 1 m borders. Three cool-season annual forages were individually sown into a whipgrass sward and compared with a whipgrass control, with treatments arranged in a randomised complete block design replicated 4 times. All treatments were repeated in the same plots each year. The annual forages were triticale (*Triticosecale* spp.) cv. Zhongsi 828, rye (*Secale cereale*) cv. Dongmu 70 and annual ryegrass (*Lolium multiflorum*) cv. Changjiang No 2.

The triticale and rye were sown at 96 kg/ha and 48 kg/ha, respectively, and ryegrass at 24 kg/ha. Plots were prepared for planting by clipping the whipgrass at a cutting height of 2.5 cm. Pastures were disced lightly with a no-till drill and seed was broadcast on September 8, 2005 and September 11, 2006. Pastures were then harrowed lightly to help incorporate seed. Fertiliser (60 kg/ha N, 10 kg/ha P and 20 kg/ha K) was broadcast on to the plots in late November, and an additional 56 kg/ha N in early February. Broadleaf weeds growing in the plots were controlled by hand weeding. All annuals established and produced good stands. Plant density in the plots was not recorded, but typically ryegrass produced denser stands than triticale and rye.

Autumn harvests were made in late November or early December at a cutting height of 10 cm to permit regrowth of cool-season annuals. Subsequent harvests were at a cutting height of 5 cm. The first spring harvest was in early March. Three cuts were made in the spring, and a further 3 in the summer.

At harvests in autumn and spring, maturity ratings were made for the oversown species. Samples for botanical composition were taken in two 0.09 m^2 quadrats per plot by hand-clipping and

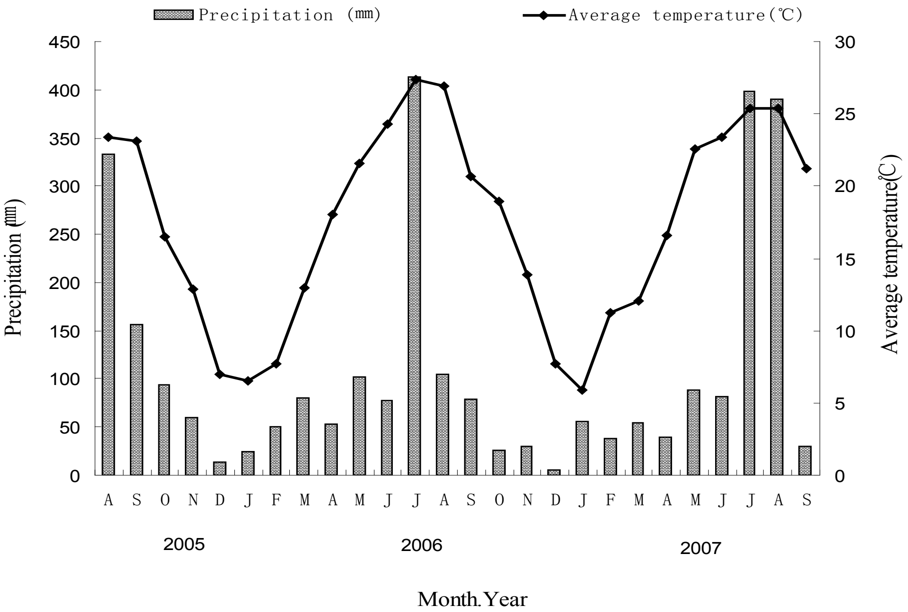

Figure 1. Summary of monthly precipitation and mean monthly temperature during the experimental period (Aug 2005-Sep 2007) in Ya'an.

these were hand-separated into components of whipgrass and individual oversown species. The separated components were oven-dried at 65℃ to estimate the whipgrass and oversown species proportions on a dry matter basis. Botanical composition was also used to explain chemical differences among treatments.

Yield was measured on a 1 m × 5 m swath cut through the centre of each plot. Fresh material was weighed and fresh forage samples (1 kg) were collected in muslin bags, dried at 65℃ for 72 h and weighed to determine dry matter yields. Dried subsamples were ground in a laboratory mill to pass a 1 mm screen before forage chemical analysis.

Total N concentration was determined by the macro-Kjeldahl procedure and neutral detergent fibre using the methods of Goering and van Soest (Zhang 2002). Sodium sulfite and heat-stable α-amylase were used in the NDF procedure (Zhang 2002). Forage nutritive value was analysed separately for forage from each harvest.

Cumulative DM yields and nutrient concentrations were also calculated for sequential harvests within the whole year. Analysis of variance for DM yield, crude protein (CP) and NDF was performed using the mixed procedure of SPSS 11.5. Whipgrass presence, annual species type and the whipgrass × annual species interaction were considered fixed effects. Environment (the interaction of year) and replication were considered random effects. If there were significant differences among treatments, mean separations were made with the PDIFF option. Dry matter yield was divided into autumn (Harvest 1), spring (Harvests 2–4), summer (Harvests 5–7) and total for those treatments that were harvested 7 times (Table 1).

Table 1. Harvest dates for Year 1 and Year 2. Year 1 was the autumn to autumn of 2005-2006 and Year 2 was the same time for 2006-2007.

	Year 1	Year 2
Harvest time	Nov 25-27, Mar 1-4, Apr 7-13, Apr 21-29, Jun 3, Jul 8, Sep 6	Nov 28-Dec 4, Mar 3-5, Apr 9-11, Apr 23-26, Jun 4, Jul 11, Sep 7

Results

Dry matter yield

Cumulative DM yields were consistently higher in oversown plots than in the whipgrass (WG) control treatment at the 7 harvests (Figure 2). Mean cumulative DM yields through 7 successive harvests in 2006 showed the following pattern: WG-ryegrass (38.23 t/ha) > WG-rye (35.86 t/ha) and WG-triticale (36.12 t/ha) > WG (control) (25.48 t/ha) ($P<0.05$) (Figure 2). A similar pattern emerged in 2007 with mean total cumulative yields in WG-ryegrass (37.57 t/ha DM) > WG-rye (34.73 t/ha) and WG-triticale (35.09 t/ha) > control (22.99 t/ha) (Figure 2).

Cumulative DM yields in the ryegrass plots were consistently higher than in the triticale and rye treatments at the second harvest (Figure 2). In autumn (Harvest 1), forage yields of all mixtures were 1.62 t/ha higher on average than that of whipgrass monoculture (Figure 3). In spring (Harvests 2–4), ryegrass treatments showed higher yields in both 2006 and 2007 than rye and triticale ($P<0.05$), while all oversown treatments outyielded ($P<0.05$) the control. In summer (Harvests 5–7), yield differences between all treatments were generally small (Figure 3). Although treatment differences were not always significant, the control treatment consistently ranked lowest in DM yield in autumn-spring (Figure 3).

Forage composition

Whipgrass came out of dormancy earlier in spring in control plots than in the oversown plots, probably owing to reduced ground cover. Control plots yielded a mixture of winter annual weeds and whipgrass at the first and second spring harvests, and predominantly whipgrass at the third harvest each year. However, oversown plots yielded predominantly cool-season annual forages at the first and second harvests and a mixture of cool-season annuals and whipgrass at the third harvest. In spring for all mixtures, more than 60% of the available forage was from oversown species (Figure 3). By early June, at the time of the fifth harvest in the present study, all plots were virtually whipgrass monocultures (Figure 3).

Maturity at harvest

There were differences in maturity among oversown species at each harvest. Ryegrass matured

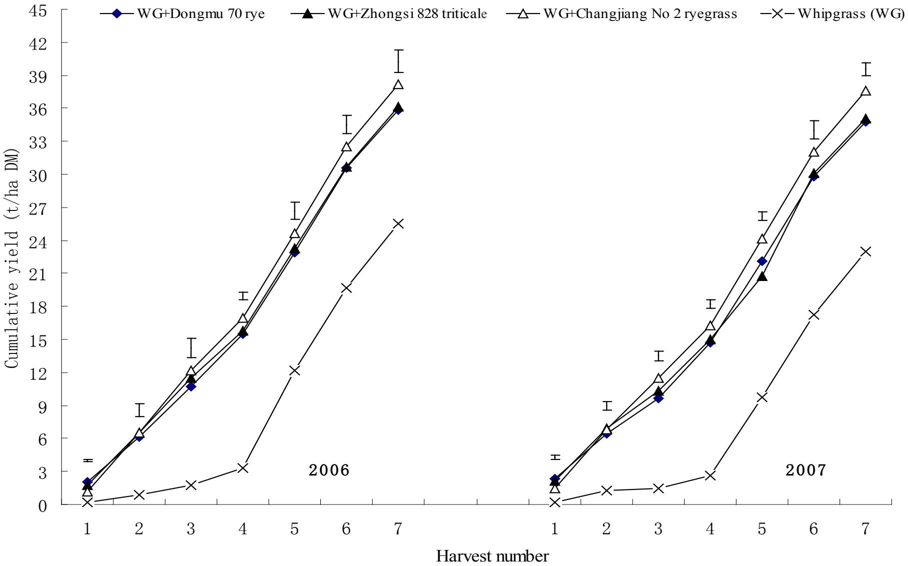

Figure 2. Cumulative forage dry matter (DM) yields over 7 harvests for whipgrass plots (control) and whipgrass plots oversown with 3 winter annuals in early autumn.

later than triticale and rye, which bloomed in mid-March and produced little re-growth after the second harvest. During autumn, Dongmu 70 rye and Zhongsi 828 triticale were more mature than Changjiang No 2 ryegrass, being at the stem-elongation stage while ryegrass was tillering. At the first spring harvest, triticale and rye were in the early boot stage, with ryegrass at the stem-elongation stage. These differences in maturity at harvest may explain some of the observed differences in forage quality in mixtures.

Forage quality

Crude protein (CP) concentration generally decreased as the growing season progressed (Table 2). In autumn (Harvest 1), CP concentrations in mixtures of whipgrass with rye and triticale were similar in autumn and spring (mean 158.9 g/kg; Table 2), but lower ($P<0.05$) than those for whipgrass and whipgrass-ryegrass (mean 181.8 g/kg). In spring, CP concentrations at harvests 2 and 3 were also higher in whipgrass and whipgrass-ryegrass. CP was approximately 4.2 percentage units greater in autumn than in spring. CP concentration in summer for all treatments was similar (mean 78 g/kg).

NDF concentration in whipgrass was lower than in whipgrass-ryegrass, which was lower than in mixtures of rye and triticale with whipgrass at harvests 1 and 2 ($P<0.05$). By summer, NDF concentrations had increased and differences between treatments were minimal.

Discussion

This study has shown that small grains and ryegrass can be successfully oversown in autumn into whipgrass swards in these areas of southwest China without the use of herbicides. Oversowing these species resulted in a massive increase (9.2–10.7 t/ha DM) in forage production in autumn and spring, which was comprised of the oversown species (Figure 3). The oversown species have the ability to grow satisfactorily at low temperatures, while whipgrass is largely dormant during this period and does not produce rapid growth until summer. Although summer growth in all pastures was similar, the increased autumn-spring growth resulted in annual DM production of the mixed pastures exceeding that of

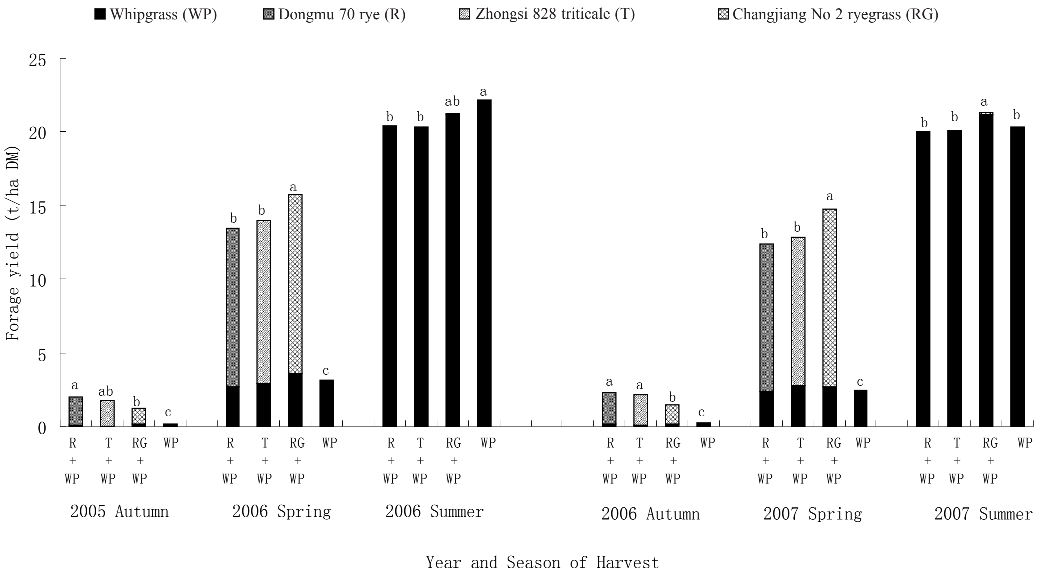

Figure 3. Cumulative forage dry matter (DM) yields from 1 autumn, 3 spring and 3 summer harvests in each of 2 years from whipgrass plots and whipgrass plots oversown with 3 winter annuals in early autumn. Within seasons, columns with different letters were significantly different ($P<0.05$) for seasonal forage yield.

Table 2. Crude protein (CP) and neutral detergent fibre (NDF) concentrations of forage from whipgrass and over-sown whipgrass swards at different harvests. Values are means of 2 years.

Treatment	Harvests						
	1	2	3	4	5	6	7
				CP (g/kg)			
WG plus Dongmu70 rye	158.6b[1]	126.9b	116.4b	113.6	83.2	81.4	79.8
WG plus Zhongsi 828 triticale	159.3b	131.4b	120.6b	117.4	84.1	77.5	78.4
WG plus Changjiang No 2 ryegrass	178.4a	142.1ab	136.5a	122.7	82.9	79.3	75.3
Whipgrass (control)	185.1a	150.4a	143.8a	120.9	81.2	76.9	77.1
s.e.[2]	15.2	16.1	13.9	7.9	5.7	6.2	8.4
				NDF (g/kg)			
WG plus Dongmu70 rye	348.2b	499.1c	502.3b	512.4	581.3	593.4	597.1
WG plus Zhongsi 828 triticale	331.1b	404.6b	467.4ab	519.2	577.3	586.9	591.4
WG plus Changjiang No 2 ryegrass	329.6b	391.4b	451.3a	524.7	581.8	583.6	594.2
Whipgrass (control)	309.4a	334.5a	442.7a	508.2	576.3	582.4	588.6
s.e.	31.4	55.8	39.7	26.3	11.9	20.1	17.4

[1] Within parameters, means within a column followed by different letters are significantly different at $P<0.05$.

[2] s.e. is for comparison of treatment means between monoculture and mixture within attributes.

pure whipgrass by 46–56%. However, only mixtures of ryegrass and whipgrass produced forage of similar quality to pure whipgrass swards. Early onset of maturity in rye and triticale resulted in forage produced being of inferior quality to that from whipgrass or the ryegrass-whipgrass mixture in spring.

Successful oversowing of cool-season forages into warm-season grass pastures depends on many factors such as reducing warm-season grass competition in autumn, optimal planting date, selection of correct cool-season annual species, seeding rates, planting methods, etc. The sowing method employed in our study of clipping whipgrass to 2.5 cm, followed by light discing before broadcasting seed and lightly harrowing it into the ground obviously caused sufficient setback for the whipgrass in autumn to allow seedlings of the cool-season forages to establish successfully. While growth of whipgrass was reduced initially, results indicated that it had the ability to recover from these temporary setbacks and produce similar yields to untreated areas by the following summer. Whipgrass has stolons that make it very tolerant of close, frequent defoliation (Wu and Du 1992). Persistence under continuous, heavy grazing/cutting was one of the reasons for its widespread use. Under continuous grazing/cutting, the stolons form a tight prostrate sod that shades the soil surface, providing strong competition for emerging annual forage seedlings. A more upright growth and open sod can be encouraged if the whipgrass is allowed to grow undefoliated for 4–5 weeks before oversowing. The top growth can be removed as hay or by ‘crash grazing’. The more open sod allows sunlight to reach the soil surface and is less competitive for emerging seedlings. Date of planting is important, with recommendations to oversow cool-season annuals from 4–6 weeks before the average first killing frost date. From the cool-season forage standpoint, planting should be as early as possible when night minimum temperatures drop to 15℃ with day temperatures about 27℃ (Moser *et al*. 1996). In our study in south-west China, germination and seedling growth were rapid under the prevailing temperatures, when we planted in early September. Other studies (Hossain *et al*. 2003; Arzadún *et al*. 2006) have shown that, as planting was delayed, cooler temperatures slowed germination rate and seedling growth, resulting in lower autumn and winter forage production. However, the risk with early planting is that periods of high temperatures and/or limited rainfall following planting, could result in stand reduction or total loss of the oversown species. In addition, when cool-season forages are planted early, they also have to compete with a more vigorous whipgrass sward.

Annual ryegrass, rye, triticale, wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and oats (*Avena sativa*) are the primary forages used for oversowing into warm-season perennial grasses (Bartholomew and Williams 2007). While all annual species that we tested produced well, ryegrass had distinct advantages over rye and triticale. Although rye and triticale provided slightly more forage production in autumn than annual ryegrass, annual ryegrass was more productive in spring (Figure 3). Mid to late spring is the other period when the growing seasons of the oversown species and whipgrass overlap. With late-maturing ryegrass varieties, recovery of whipgrass can be slow in a dry spring, because the oversown species has depleted the soil moisture. For this reason, management practices such as heavy cutting or grazing might be needed in late spring to control the oversown species and enhance recovery of whipgrass.

In autumn-spring, quality of forage depended on the particular oversown species component and its maturity. Mixtures containing rye and triticale had lower CP concentrations than mixtures containing ryegrass because the whipgrass proportion in the whipgrass-ryegrass mixture was higher than in the other mixtures in late spring (Table 2). Typically, mature warm-season grasses have lower crude protein concentrations than cool-season grasses (Table 2), and greater concentrations of NDF (cell wall components such as cellulose and hemicellulose). Moreover, rye and triticale were more mature than ryegrass at harvest.

The marked reduction in forage quality in summer would be largely a function of stage of maturity. In general, as grass plants mature, the number and size of reproductive stems increase and nutritional value declines (Burns *et al*. 1997). Reduced growth rate as the season progresses dilutes the proportion of new growth of high quality with older growth of low quality. An additional factor is the increased production of culms and their maturation. Temperature is another key factor, as increased growth temperature reduces whipgrass dry matter digestibility (DMD) (Wu *et al*. 1989). As temperature increases, stem development and stem maturation are accelerated, leading to a decrease in whipgrass DMD. Higher temperatures also accelerate leaf maturation, leading to a faster decline in leaf DMD as leaves age and senesce (Yang 2004; Fu *et al.* 2008).

Based on current research and knowledge of performance of these grasses in other situations in south-west China, ryegrass, rye or triticale can be sown into whipgrass in autumn to produce high-quality forage in late autumn and the following early spring. This would advance the production window for high-quality forage about 4 months before the normal harvest season for whipgrass, and even earlier if the sward is grazed.

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