RESPONSE OF RHODES GRASS (*Chloris gayana* Kunth) TO VARIABLE RATE APPLICATION OF IRRIGATION WATER AND FERTILIZER NITROGEN

V.C. Patil, K.A. Al-Gaadi, R. Madugundu, E. Tola, S.A. Marey,

Precision Agriculture Research Chair
Department of Agricultural Engineering
College of Food and Agriculture Sciences
King Saud University
Riyadh, Saudi Arabia

D.J. Mulla

Department of Soil, Water and Climate
University of Minnesota
St. Paul, Minnesota, USA

S.K. Upadhyaya

Department of Biological and Agricultural Engineering
University of California
Davis, California, USA

ABSTRACT

Rhodes grass is cultivated extensively in Saudi Arabia under center pivot sprinkler irrigation system. The research work was carried out to optimize irrigation water and fertilizer nitrogen levels for the crop. The objectives of the study were: (1) to delineate the field into management zones, and (2) to study the effects of variable rate application (VRA) of irrigation water and fertilizer nitrogen on the yield of Rhodes grass. A field experiment was carried out from June to November 2012, on a 50 ha farmer's field irrigated by center pivot. The experimental field was divided into two management zones (MZ). Spilt-split plot design was employed with MZ as two main treatments. Sub-treatments were: irrigation at 100, 80, 60 and 40% crop evapotranspiration (ET_c); and sub-sub treatments were nitrogen fertilizer levels of 240, 480, 720, 960 and 1200 kg/ha. The mean productivity across three cuts was higher in MZ 2 (8.16 t/ha/cut) than in MZ 1 (7.26 t/ha/cut). The effects of treatments were significant in the last two harvests but not in the first harvest. Significant differences between the management zones were observed only with respect to nitrogen levels but not with respect to irrigation levels. However, deficit irrigation was found to be beneficial in both zones. Across the zones, irrigation at 80 and 60% ETc resulted in higher hay yields in second and third harvests, respectively. By increasing the nitrogen level from 240 to 480 kg/ha, the hay yield increased from 7.58 to 8.46 t/ha/harvest, only in MZ 2, indicating the possible benefit of variable rate application of fertilizer nitrogen. Based on this study, the following conclusions can be drawn: (i) deficit irrigation can be adopted for Rhodes grass by irrigating the crop at 80% ET_c for the first two harvests and at 60% ET_c for the last/subsequent harvests. 2. Fertilizer nitrogen use can be optimized by adopting VRA technology.

Keywords: Irrigation, nitrogen, precision agriculture, Rhodes grass, variable rate application.

INTRODUCTION

Rhodes grass, a pasture grass from West and South Africa, is one of the most widely grown forage grasses in warm countries. The grass is cultivated extensively in Saudi Arabia due to its good drought and salt tolerance features that make it a good choice for dry locations. The crop responds well to irrigation. Rhodes and blue panic grasses consume high amounts of water ranging from 35000 – 45000 m^3/ha/year (Al-Doss, 1997). Dry matter production of 24 to 26 t/ha was reported from the irrigated fields in the Mediterranean-type climate of south-west Australia (Roberts and Carbon, 1969). Vaisman et al. (1982) obtained dry matter yield of 12 t/ha by applying irrigation water on the basis of 0.8 pan factor.

It is reported to be responsive to N fertilizer (Farnworth and Ruxton, 1974). Like other grass species Rhodes grass requires heavy nitrogen (N) fertilization in order to produce high forage yields. However, heavy N-fertilization causes accumulation of free nitrate in the forage which is unfavorable for cattle (Guggenheim and Waisel, 1977). Spectacular linear response to nitrogen at rates of 275-400 kg/ha in the presence of adequate phosphorus and potassium, both in yield and in crude protein content was reported; and split applications after each cut or after grazing cycles were found better than one basic application (FAO, 1978). Rhodes grass was reported to respond to N rates as high as 1200 kg/ha/year under center pivot irrigation at Marmul in virgin desert soils and provide an annual dry matter yield of 35 t/ha (Anonymous, 1988). Prakash et al. (1994) observed curvilinear response to nitrogen fertilization with highest rate of 840 kg/ha/year increased Rhodes grass dry matter yields from 13 to 53 t/ha/yr and recommended application of N @ 120 kg/ha/harvest. Vaisman et al. (1982) obtained dry matter yield of 12 t/ha by applying 250 kg/ha of nitrogen to Rhodes grass.

In Saudi Arabia, the crop is grown under center pivot sprinkler irrigation system. There are no reports of the effects of variable rate application of irrigation and fertilizer levels on the productivity of Rhodes grass from Saudi Arabia. Therefore the present research work was carried out with the following objectives: (1) to delineate the field in to management zones, and (2) to study the effect of Variable Rate Application (VRA) of irrigation water and fertilizer nitrogen on the hay yield of Rhodes grass.

MATERIAL AND METHODS

The experiment was conducted on a commercial farm (Todhia Arable Farm-TAF) located between Al-Kharj and Haradh regions of Saudi Arabia within the latitudes of 24º10' 22.77" and 24º12' 37.25" N and the longitudes of 47º56' 14.60" and 48º05' 08.56" E.

Delineation of management zones

A management zone is a sub-region of field which is relatively homogenous. The management zone map of the field is depicted in Fig 1A (taken from Patil et al., 2014). The experiment was conducted in Pivot Field TE-11 after the harvest of wheat crop.

Experimental details

The experiment was laid out on clay loam soil with a pH of 7.58. The soil contained 72.53 (± 8.41) mg kg^{-1} (nitrogen, N), 5.35 (± 3.58) mg kg^{-1} (Phosphorus, P) and 60.81 (± 28.27) mg kg^{-1} (Potassium, K). The ground water used for irrigation had EC, pH, Sodium Absorption Ratio (SAR) of 3.178 (dSm^{-1}), 7.21 and 1.29, respectively. The field experiment was carried out from June to November 2012, on a field irrigated by center pivot system. The experimental field was divided into two management zones (MZ). Spilt-split plot design was employed with MZ as two main treatments. Sub-treatments were: irrigation at I1-100, I2-80, I3-60 and I4-40% crop evapotranspiration (ET_c); and sub-sub treatments were nitrogen levels: F1-240, F2-480, F3-720, F4-960 and F5-1200 kg/ha. Treatments were imposed by Variable Rate Irrigation (VRI) system of Valley Irrigation, USA. The experimental layout plan is given in Fig. 1B. Prescription maps for VRI are given in Fig.2.

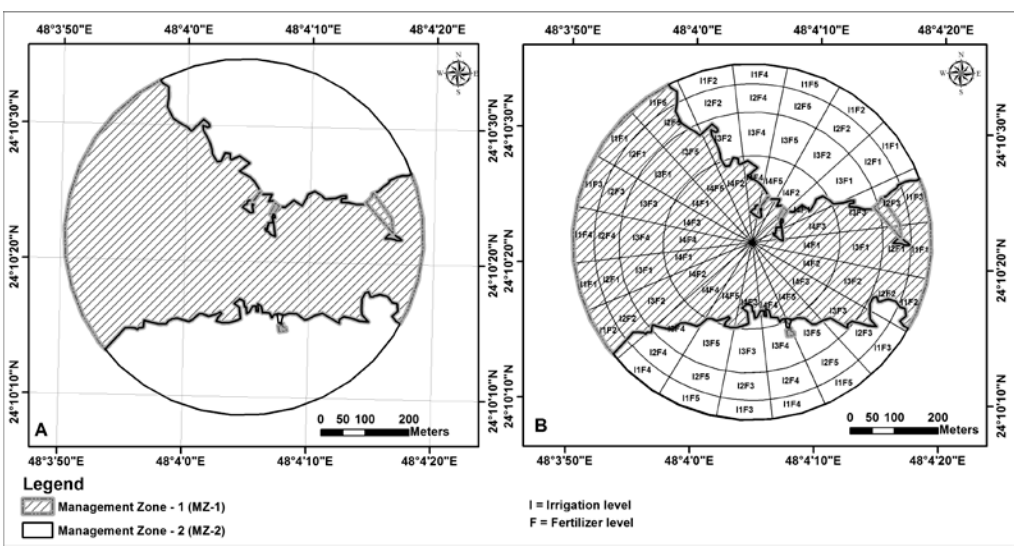

Fig. 1 Experimental layout of Rhodes grass field: (A) Management Zone map and (B) Layout of treatments (Taken from Patil et al., 2014)

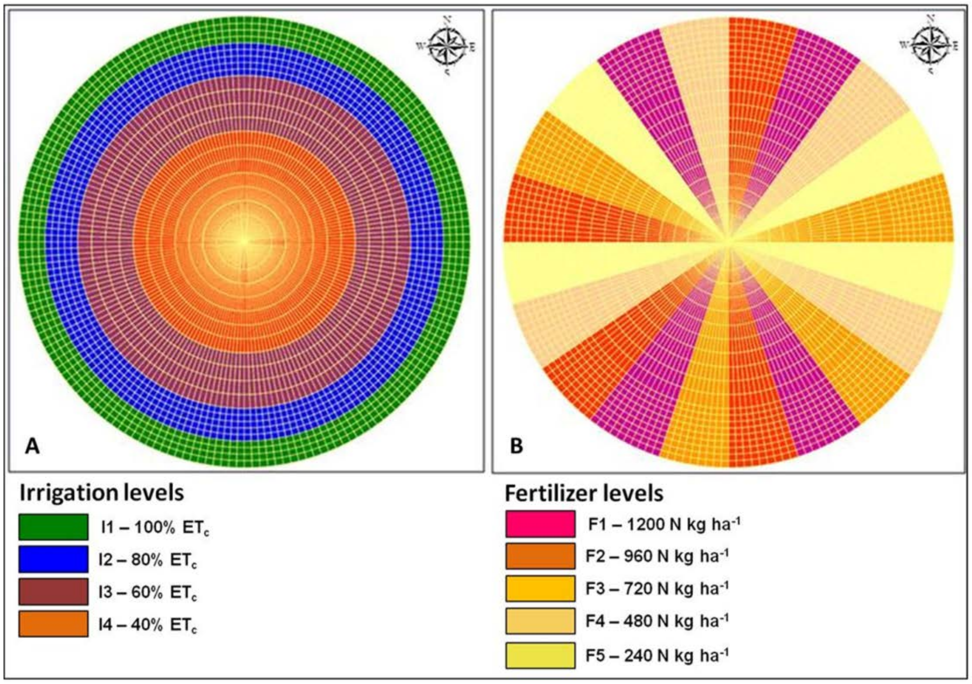

Fig. 2. Prescription maps for Variable Rate Application (VRA) system: (A) Irrigation levels and (B) Fertilizer Nitrogen levels

Rhodes grass hay yield mapping

The hay yield monitor (Model 880) of Harvest Tec, USA was installed on a large square baler (Claas 3200) to record the harvested yields. Rhodes grass yield of three cuts made in July, September and October 2012 was recorded at the time of baling with constant pressure of 55 to 60 bars and the vehicle speed of about 10 – 15 km/h. Moisture content for 100 bales, that were weighed, was measured using a moisture probe (Delmhorst F-2000, Digital Hay Moisture Meter with 18 Inch Probe). The moisture content of the bales varied from 9.8 to 12.2%, and the majority of the bales showed a moisture content of about 10.5%. Hence the weight of 100 bales was normalized to 10.5% moisture content. Yield monitor data was filtered using automated low pass filter of Erdas Imagine (Ver. 2010). The yield maps depicted in Fig. 3 were prepared by interpolating the filtered point data to a 4 by 4 m grid using the ordinary kriging (Dobermann et al., 2003) tool of ESRI GIS (Ver. 2010). During the preparation of yield maps, low or high yielding strips and points associated with significant turning and maneuvering of the baler were removed as described by Wiebold et al. (2003). Short segments which were affected by start or end-pass delays were also removed as described Simbahan et al. (2004).

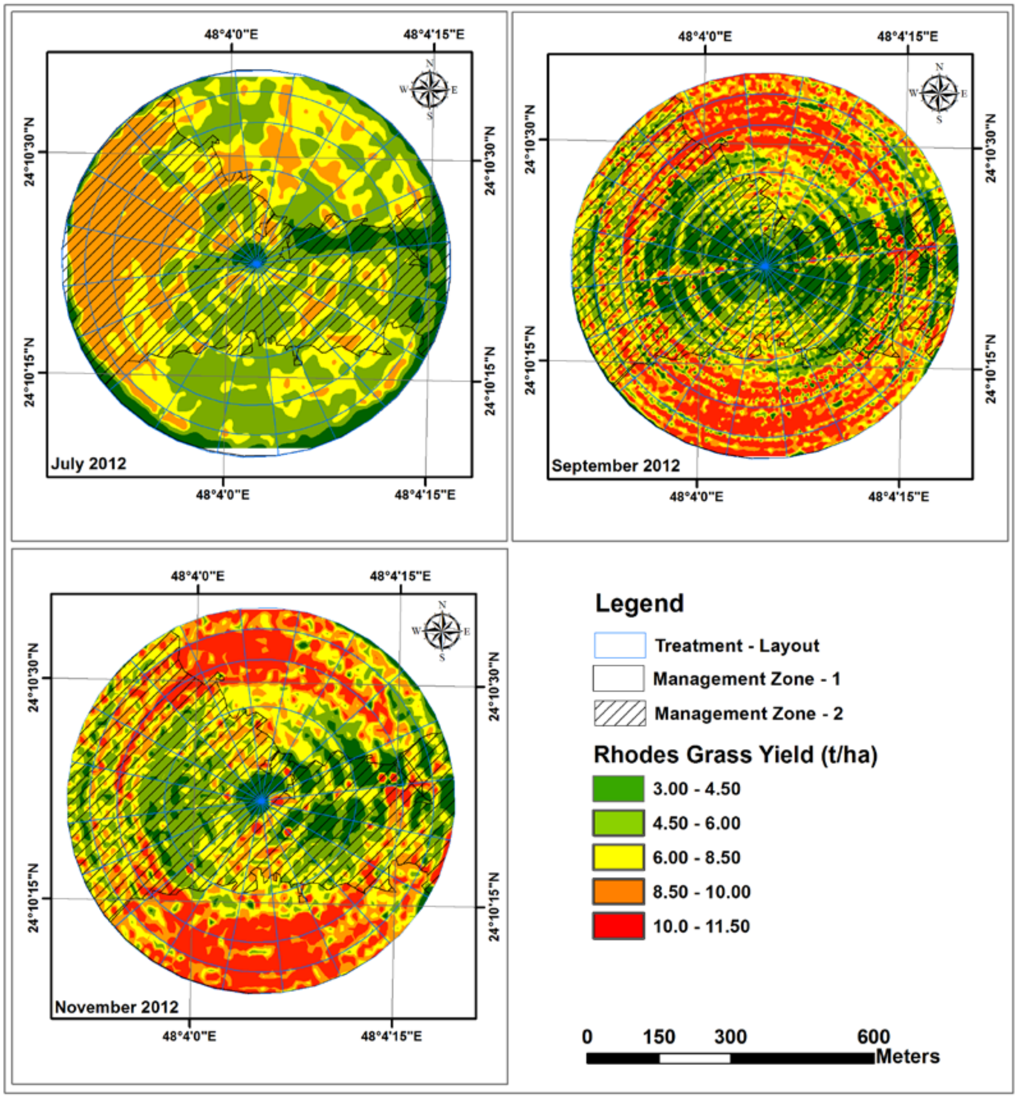

Fig.3 Rhodes grass yield maps developed from yield monitor data

RESULTS AND DISCUSSION

The hay yield observations of Rhodes grass, recorded using the hay yield monitor, are presented in Tables 1-3. The mean hay yield data across three harvests was higher in MZ-2 (8.16 t/ha/harvest) than in MZ-1 (7.26 t/ha/harvest). However, the differences in the hay yield between the zones were not statistically significant in July 2012 harvest. But, in the subsequent two harvests, MZ-2 recorded significantly higher hay yield than MZ-1.

Variable rate application of irrigation water proved advantageous in one (July) out of three harvests. In July harvest, all the three deficit irrigation treatments (irrigation at 80, 60 and 40%ET_c) recorded significantly higher yield than irrigation at 100% ET_c in MZ-2. But in MZ-1, irrigation at 80 and 60% ET_c were superior to 100% ET_c. In September harvest, irrigation at 80% ET_c recorded significantly higher yield than the other three irrigation levels across zones. Whereas in November harvest, irrigation at 40% ET_c resulted in significantly lower yield than the other irrigation levels; while the other three irrigation levels were at par. Irrigation at 80% ET_c for the first two harvests and at 60 % ET_c for the third harvest was beneficial.

Variable rate application of fertilizer nitrogen was beneficial only in September harvest. In this harvest, across zones and irrigation levels, an increase in the nitrogen level from 240 to 480 kg/ha increased the yield from 6.74 to 7.76 t/ha. In the other two harvests made in July and November, increase in the levels of nitrogen did not result in yield enhancement. Nitrogen application at 480 kg/ha for MZ-2 and 1200 kg/ha for MZ-1 proved significantly superior to the other levels.

By increasing the nitrogen level from 240 to 480 kg/ha, the hay yield increased from 7.58 to 8.46 t/ha/harvest, only in MZ-2, that indicated the benefit of variable rate application of fertilizer nitrogen.

Based on this study, it can be concluded that: (1) MZ-2 is more productive than MZ-1, (2) across management zones, irrigation at 80% during the initial period (first two harvests) and at 60% ET_c later will result in saving 20 to 40% of irrigation water, and (3) for MZ-2, increasing the nitrogen level from 240 to 480 kg/ha will help in optimizing fertilizer N use.

Table 1. Effect of VRA of irrigation water and fertilizer nitrogen on Rhodes grass hay yield (July 2012 harvest)

F	MZ – 1					MZ -2					OM
	I1	**I2**	**I3**	**I4**	**M**	**I1**	**I2**	**I3**	**I4**	**M**	
F1	7.41	7.60	7.63	7.49	7.53	7.44	7.49	7.56	7.43	7.48	7.51
F2	7.27	7.52	7.57	7.49	7.46	7.34	7.60	7.57	7.58	7.52	7.49
F3	7.44	7.57	7.48	7.47	7.49	7.42	7.52	7.52	7.55	7.50	7.50
F4	7.67	7.73	7.59	7.54	7.63	7.34	7.56	7.56	7.58	7.51	7.57
F5	7.58	7.63	7.57	7.52	7.57	7.34	7.55	7.55	7.60	7.51	7.54
OM	**7.47**	**7.61**	**7.57**	**7.50**	**7.54**	**7.38**	**7.54**	**7.55**	**7.55**	**7.51**	**7.52**

	$LSD_{0.05}$
1) Management Zones (MZ)	NS
2) Irrigation Levels (I)	0.058
3) Fertilizer Levels (F)	NS
4) Management Zone Vs. Irrigation Levels (MZ * I)	0.082
5) Management Zone Vs. Irrigation Levels (Eg. MZ_1I_1 Vs MZ_2I_1)	0.084
6) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_1F_2)	NS
7) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_2F_1)	NS
8) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_1F_2)	NS
9) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_2F_1)	NS
10) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_1F_2$)	NS
11) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_2F_1$)	NS
12) Management Zone, Irrigation Vs. Fertilizer Levels (Eg.$MZ_1I_1F_1$ Vs $MZ_2I_1F_1$)	NS

MZ = Management zones; I = Irrigation levels; F = Fertilizer levels; M = Mean; OM = Overall mean

Table 2. Effect of VRA of irrigation water and fertilizer nitrogen on Rhodes grass hay yield (September 2012 harvest)

F	MZ – 1					MZ -2					OM
	I1	I2	I3	I4	M	I1	I2	I3	I4	M	
F1	6.38	7.63	6.29	5.48	6.44	6.99	7.68	7.37	6.14	7.04	6.74
F2	7.48	8.39	6.59	5.31	6.94	8.56	9.68	8.64	7.47	8.59	7.76
F3	6.67	7.19	6.31	5.19	6.34	8.77	9.72	8.52	6.34	8.34	7.34
F4	5.59	7.38	6.57	5.84	6.34	9.46	10.36	8.82	7.90	9.13	7.74
F5	7.54	9.66	7.93	6.17	7.82	8.86	10.02	8.67	7.47	8.75	8.29
OM	**6.73**	**8.05**	**6.74**	**5.60**	**6.78**	**8.53**	**9.49**	**8.40**	**7.06**	**8.37**	**7.57**

	$LSD_{0.05}$
1) Management Zones (MZ)	0.493
2) Irrigation Levels (I)	0.392
3) Fertilizer Levels (F)	0.432
4) Management Zone Vs. Irrigation Levels (MZ * I)	NS
5) Management Zone Vs. Irrigation Levels (Eg. MZ_1I_1 Vs MZ_2I_1)	NS
6) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_1F_2)	0.611
7) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_2F_1)	0.508
8) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_1F_2)	NS
9) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_2F_1)	NS
10) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_1F_2$)	NS
11) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_2F_1$)	NS
12) Management Zone, Irrigation Vs. Fertilizer Levels (Eg.$MZ_1I_1F_1$ Vs $MZ_2I_1F_1$)	NS

MZ = Management zones; I = Irrigation levels; F = Fertilizer levels; M = Mean; OM = Overall mean

Table 3. Effect of VRA of irrigation water and fertilizer nitrogen on Rhodes grass hay yield (November 2012 harvest)

F	MZ - 1					MZ -2					OM
	I1	I2	I3	I4	M	I1	I2	I3	I4	M	
F1	6.72	7.34	8.60	8.27	7.73	7.52	9.11	8.26	8.04	8.23	7.98
F2	7.99	8.79	7.96	6.38	7.78	9.10	10.46	10.29	7.23	9.27	8.52
F3	7.94	8.77	6.67	4.97	7.08	9.74	8.93	7.98	7.31	8.49	7.79
F4	6.71	5.95	7.72	6.96	6.83	9.32	6.42	8.67	7.58	8.00	7.42
F5	8.43	7.29	9.07	6.81	7.90	9.04	8.51	10.69	7.72	8.99	8.44
OM	**7.56**	**7.63**	**8.00**	**6.68**	**7.47**	**8.94**	**8.69**	**9.18**	**7.58**	**8.60**	**8.03**

	$LSD_{0.05}$
1) Management Zones (MZ)	3.598
2) Irrigation Levels (I)	0.509
3) Fertilizer Levels (F)	0.630
4) Management Zone Vs. Irrigation Levels (MZ * I)	NS
5) Management Zone Vs. Irrigation Levels (Eg. MZ_1I_1 Vs MZ_2I_1)	NS
6) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_1F_2)	NS
7) Management Zone Vs. Fertilizer Levels (Eg. MZ_1F_1 Vs MZ_2F_1)	NS
8) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_1F_2)	1.261
9) Irrigation Levels Vs. Fertilizer Levels (Eg. I_1F_1 Vs I_2F_1)	0.451
10) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_1F_2$)	NS
11) Management Zone, Irrigation Vs. Fertilizer Levels (Eg. $MZ_1I_1F_1$ Vs $MZ_1I_2F_1$)	NS
12) Management Zone, Irrigation Vs. Fertilizer Levels (Eg.$MZ_1I_1F_1$ Vs $MZ_2I_1F_1$)	NS

MZ = Management zones; I = Irrigation levels; F = Fertilizer levels; M = Mean; OM = Overall mean

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