Table S1. Definitions of abbreviations.

AB	aboveground biomass	**NPFP**	nitrogen partial factor productivity
AIC	Akaike's information criterion	**NRC**	contribution of N translocation amount from the vegetative organ to the grain
ANOVA	analysis of variance		
ET0	potential evapotranspiration		
GOF	goodness of fit	**NT**	nitrogen translocation
GY	grain yield	**NTF**	NT-related factors (NT and NTR)
K	potassium	**NTR**	nitrogen translocation ratio
LSD	Fisher's least significant difference	**NUE**	agronomic efficiency of nitrogen
		NUF	nitrogen utilization factors (NHI and NUtE)
MS	meadow soil		
N	nitrogen	**NUtE**	nitrogen utilization efficiency
NA	nitrogen accumulation	**P**	phosphorus
NAF	NA-related factors (grain NA and post-anthesis NRC)	**PLS-PM**	partial least squares path model
		W	water
NDR	nitrogen distribution ratio	**WRB**	World Reference Base for Soil Resources
NHI	nitrogen harvest index		

Table S2. The statistics of the outer model in PLS-PM

	Item	Weight	Communality	Redundancy
NAF	Grain NA	0.744	0.866	0.759
	Post-anthesis NRC	–0.411	0.562	0.492
NTF	NT	0.643	0.744	0.724
	NTR	–0.552	0.653	0.635
NUF	NHI	0.593	0.912	0.891
	NUtE	0.468	0.858	0.839

Grain NA: Grain nitrogen accumulation; Post-anthesis NRC: Contribution of N translocation amount from the vegetative organ to the grain at post anthesis; NT: Nitrogen translocation; NTR: Nitrogen translocation ratio; NHI: Nitrogen harvest index. NUtE: Nitrogen utilization efficiency; NTF: NT-related factors, including NT and NTR; NUF: nitrogen utilization factors, including NHI and NUtE.

Table S3. The statistics of the regression analysis model

Independent variables	DF	SQ	RSS	AIC
– NUtE	1	1583031	1623931	278.94
– Grain NA	1	94332	135232	219.28
– Post-anthesis NRC	1	24594	65494	201.88
– NTR	1	21035	61935	200.54
– NT	1	20783	61683	200.44
– NHI	1	9064	49964	195.38
Stepwise regression model			40900	192.58

The "–" indicate deletions. DF: degree of freedom.; SQ: sum of squares; RSS: residual sum of squares; AIC: value of the Akaike information criterion. NUtE: Nitrogen utilization efficiency; Grain NA: Grain nitrogen accumulation; Post-anthesis NRC: Contribution of N translocation amount from the vegetative organ to the grain at post anthesis; NTR: Nitrogen translocation ratio; NT: Nitrogen translocation; NHI: Nitrogen harvest index.

Table S4. The statistics of the inner model in PLS-PM

Variables	R^2	Block Communality	Mean Redundancy	AVE
NAF	0.876	0.714	0.626	0.714
NTF	0.973	0.699	0.68	0.699
NUF	0.978	0.885	0.865	0.885
GY	0.986	1	0.986	1

R^2: Coefficients of Determination; AVE: Average Variance Extracted; NAF: NA-related factors, including grain NA and post-anthesis NRC; NTF: NT-related factors, including NT and NTR; NUF: nitrogen utilization factors, including NHI and NUtE; GY: Grain yield.
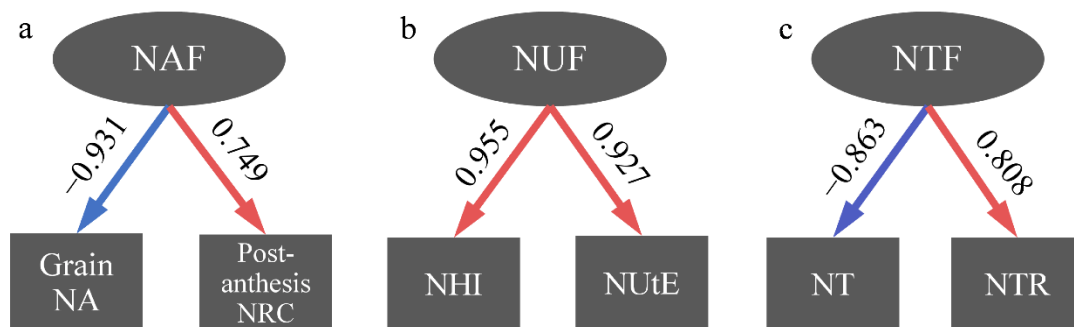
Figure S1. Path loadings of the outer model for NAF (**a**), NUF(**b**) and NTF (**c**). Path coefficients are shown alongside paths (red arrow = positive; blue arrow = negative). Grain NA: Grain nitrogen accumulation; Post-anthesis NRC: Contribution of N translocation amount from the vegetative organ to the grain at post anthesis; NHI: Nitrogen harvest index. NUtE: Nitrogen utilization efficiency; NT: Nitrogen translocation; NTR: Nitrogen translocation ratio; NTF: NT-related factors, including NT and NTR; NUF: nitrogen utilization factors, including NHI and NUtE.